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FINAL FRONTIER

The Magazine of Space Exploration

January/February 1990

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Volume 3, Number 1

In these days of free speech, the Soviet people are asking the same hard question that has plagued NASA for decades: Is space exploration worth the cost? See the article on page 18. (Cover photo by Andrew Chaikin/inset photo courtesy Space Commerce Corporation.)

Features

Departments

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FROM THE PUBLISHER

Money, money, money, money.

A coule of months ago I asked your help in solving a problem—possibly the most important one facing our space program today. Namely, how are we going to pay for it? In times of volatile federal budgets, the idea was to come up with creative financing schemes to help pay for future exploration efforts.

Some of you proposed a box on the federal tax form that people could check if they wanted to give a dollar to space.

Others suggested "space bonds"—an idea that actually has been discussed from time to time in Congress.

Another person thought we could sell name-listings on a plaque or a document that would be left on the Moon or Mars. I guess it would be the "next best thing to being there."

More ambitious would be the new space agency proposed by one reader—an entirely commercial, privately owned consortium of American aerospace companies, and perhaps those of other nations as well.

On the wilder side, there was a proposal for a Pacman-like, real-life space game where players would lease time on "sweeper" satellites, with the object being to collect the most space debris in Earth orbit. And one reader suggested that the Japanese might be interested in flipping the bill for orbiting colonies if a space golf course or two were thrown in the deal as a kicker.

A motif that ran through nearly all the letters was the desire to invest in or contribute to the space program. It wasn't long ago that kids across the country saved their pennies and raised almost $300,000 to help NASA build a new orbiter. That's hardly enough for a whole space program, but if it were done on a grand scale, worldwide, who knows what could be accomplished?

As James Oberg points out in his essay beginning on page 18, Americans are no longer alone in their struggle to justify the cost of space exploration. Mother Russia is now having to face the same questions about "cost effectiveness" that NASA has been hearing since the days of Apollo.

If Soviet space officials are having a difficult time explaining themselves to their people, perhaps they should give cosmonaut Valentin Lebedev a voice (see "The Observatory," page 8). A veteran space traveler, Lebedev knows exactly what value space exploration brings to humanity, and he does a very good job of reminding us why we do it in the first place.

As we begin the 1990s, the time has come to start breaking down some of the national boundaries separating the world's space programs. When the politics are right, whenever possible, we should join our efforts to save money, not only with the Soviets but with every space-faring nation. Maybe we could start with American astronauts doing experiments on Mir and cosmonauts flying on the shuttle?

Few people think that any one country can afford to go to Mars alone. So if we make the journey together, sometime in the next century, it will probably owe as much to the accountants as to the diplomats.

Ever upward,

William Rooney

William Rooney
Publisher

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LETTERS

Grand Missions

In his "Observatory" article (July 1989), Eugene Cernan aptly emphasized the need for concrete, specific objectives for our space program to flourish. However, he seems to be living still in his glorious "Buck Rogers" days of the Apollo program in urging the setting of a "manned" Mars mission as our goal. The U.S. and the world have come a long way from the '60s and early '70s. Space is no longer a romantic crusade. We understand the costs better, and have a better sense of our fiscal limitations.

But we are also better able to estimate our opportunities and our true interests. U.S. space efforts will go nowhere beyond military objectives unless we make space pay off economically. That means developing industries and solar power satellites, and developing the resources of the Moon. It means creating habitats, which will demand huge feats of planning, engineering and finance, and probably inter-governmental cooperation. Mr. Cernan could hardly ask for a more daunting challenge.

But if he really believes we need a grand space mission, one that would appeal to more than a few macho adolescents, let's set as our goal the development of solar power satellites that will eliminate dependence on fossil fuels and dangerous nuclear reactors. We can enormously reduce pollution that sullies the environment and endangers our health. We can reduce the risk of a radioactive disaster such as Chernobyl, and may be able to ameliorate the greenhouse effect. Furthermore, we could seek ways to move to Earth orbit those industries that are fouling our air, water and soil, which are leaving a deadly legacy for future generations.

These are concrete objectives on a grand scale that can actually make a real difference in the lives of people everywhere, as a Mars mission cannot. And they will draw on our greatest technological skills and demand the ultimate in courage. The problem with the national goal of a Mars mission—no matter how far out in the future—is that, to be believable, major steps must be taken soon to achieve it.

Such steps will be costly and will drive out more worthy and immediate objectives. There is no magic in the Mars mission, for after that there is the asteriod belt, the moons of Jupiter, the moons of Saturn, and so on. The Mars mission is, in truth, an illusion and not a panacea for our space program. When you begin to tote up its costs and the possible benefits, see how rapidly Congress loses interest in the space program.

D. Allen Meyer
Phoenix, Arizona

Firestarter

With regard to Patrick Kelly's letter to the editor about the "Face on Mars" controversy (August 1989)...

Public interest in Mars was all but completely dead after the Viking landings in 1976, when space scientists on that project announced they did not find life on Mars. I think that mission did more to kill public support for planetary exploration than anything else, and we are still seeing the lasting effects of it today. It was announced back in 1962 that the purpose of planetary exploration was to search for possible extraterrestrial life on the other planets of the Solar System. When [the scientists] did not find any, gone right there was one of our biggest reasons for wanting to go to the planets.

From that time on, this part of our space program has been in suspended animation. Any evidence, however faint, that might show up indicating there perhaps once was an intelligent civilization on Mars–and that includes Hoagland's "face"–would do more than anything to rekindle public interest in exploring this planet with both unmanned and manned landings. I believe this is where the interest of the public lies in space exploration, particularly planetary exploration, and only something like that will set them on fire about it again.

Daniel Louderback
South Bend, Washington

APOLLO 11 20th ANNIVERSARY
A Benefit For The Challenger Center

COMMEMORATIVE LITHOGRAPH OFFERING
Autographed By
BUZZ ALDRIN AND MICHAEL COLLINS

It has been almost 500 years since the last great epic adventure – the discovery of the new world by **Christopher Columbus** in 1492. On **July 20, 1989**, we celebrated the 20th Anniversary of the greatest adventure – the setting foot not only on a new world, but on another world. With the landing of **Apollo 11 Eagle** on the moon in the Sea of Tranquility, **July 20, 1969,** Man for the first time broke his earthly ties and truly stepped out into the universe – **"one small step for man, one giant leap for mankind."**

In celebration of mankind's greatest and most significant achievement, two **Apollo 11 astronauts, Michael Collins and Edwin "Buzz" Aldrin**, and the artist, **James R. Cooper**, have come together to sign historic limited edition lithographs commemorating this great event, both printed on the highest quality acid free archival stock paper. Thus, a unique time valued masterpiece is created, suitable for framing, and certain to be cherished for generations by those with a profound sense of national, if not international, pride with regard to space exploration.

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The first lithograph will be signed by **Buzz Aldrin** a member of the first crew to set foot on the moon. It has been said that if there ever was a reason to go to the moon for this nation, nothing more important could be brought back to earth than the famous photograph taken by **Neil Armstrong** of **Buzz Aldrin**.

This memorable moment captured so brilliantly will be printed on archival stock approximately 21" x 26". Individually numbered, and signed by **Buzz Aldrin**, quantity is limited to 350 only.

Prior to this historic mission, **James R. Cooper**, a NASA artist, was commissioned to execute a design conceived by command module pilot, **Michael Collins**, which represented America's symbolic Bald Eagle, landing triumphantly on the moon's surface with an olive branch held gently in its talons – **"We came in peace for all mankind."**

This historic first moon landing mission emblem will be individually numbered and signed, by **Michael Collins and James Cooper**. The dimensions are approximately 26" x 26". Quantity is limited to 350 only.

The proceeds from this project, $375.00 of each purchase is tax deductible, will benefit the Challenger Center for Space Science Education, a non-profit organization founded by the families of the crew of the peace shuttle, Challenger, after the ill-fated mission. The Center is dedicated to providing motivational tools including curriculum, and learning environments around the country which will inspire our youth to become productive and technologically literate citizens in the 21st Century.

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THE OBSERVATORY

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By Valentin Lebedev

Recently we have heard about the concern the public has with how the money allocated to space technology is being spent. I'm sure you'll agree that this is the fault of those who work in the space industry and those who publicize it.

In Russia we say that whatever you sow you shall reap. So now we reap. As we developed space technology we should have been educating the public. We should have thought not only about the development of technology and solving scientific problems, but also about why the experiments were being done in the first place.

You in the United States may have begun to discuss this problem a little earlier than we have, but it is a problem for our space program we well as for yours. People are right in wanting to know what the money has been spent for. There is only so much of it to go around. If we overspend in one area, there won't be enough left in others.

We must be especially careful to remember that aeronautics and space technology are not ends in themselves; space exploration is not just a new way to conduct scientific experiments. We are opening up a new environment for human beings. We are not going there as tourists, we are going to stay, forever.

How many changes will happen in man's attitude and outlook when he begins to live in space! For example, here we are satisfied with low ceilings and height limitations. Our living area is two-dimensional. The environment of space is not that of flat surfaces, but of volumes; it is three-dimensional. We can walk on the ceilings and walls.

Space changes human psychology, our general outlook on the world, our view of Earth, art, architecture and our lives in general. We have just begun our studies in this wonderful school, and we will get a fine education. But it should not be confined to a privileged few. This education is also for all the people who earn the money to pay for the development of space technology; everyone involved in the space industry should be their teachers.

Once we thought we could do anything in our own countries. Today we understand that at our level of industrialization and social development we are all united by nature, and there is no more meaning to the words "mine" and "yours." We must use a new word—"ours." When we cosmonauts go into space, this word "ours" unites us.

We don't have to be in a hurry to set new records—who launches the most people and so forth. While we are concerned with the cost of space exploration, we should also carefully consider those who represent us in space. Those who explore space do so as representatives of their countrymen who remain on Earth. And through the eyes and minds of those explorers the rest of humanity will come to comprehend space.

Valentin Lebedev flew onboard the Salyut 7 space station for 211 days in 1982, and is the author of Diary of a Cosmonaut. *The above excerpt is from remarks he made to the 26th Space Congress in Cocoa Beach, Florida last April.*

THE GLOSS COMPANY

JANE MEYERS

Lebedev in his cosmonaut regalia and at the podium: "We are opening up a new environment for human beings."

NOTES FROM EARTH



MARGARET HUBER

BUBBLESATS

Although it doesn't yet have an official name, its creator has dubbed it the Lawrence Welk Space Bubble Factory.

Jim Stevens, a scientist at the Jet Propulsion Laboratory in Pasadena, California, is proposing a technology that he claims could vastly improve communications on Earth and yet be extremely cost-effective: plastic bubbles in space that together would act as a giant antenna.

Such an improvement in communications is needed, Stevens says, because the traditional radio frequency spectrum, which accounts for most communication on the planet–AM, FM, short wave and microwave–is becoming too crowded.

Stevens would orbit a satellite that would, in effect, blow bubbles made out of Kapton, a high-temperature polymer made by Dupont. The plastic bubbles, one inside another, would have thin printed circuits on the inside and would be coated with aluminum on the outside.

Each bubble, which could be no more than a meter in size, would be an antenna. Hundreds or thousands of them together, says Stevens, would form a giant phased array antenna in stationary orbit.

Although he has no figures on cost, Stevens says such a system would be relatively cheap to produce and could be in operation within a matter of months. "All you would need is an ordinary spacecraft with a computer, a tank of plastic and a bubble machine similar to the one used by Lawrence Welk on his television show."

A large phased array antenna in Earth orbit could separate communications systems spatially, thereby giving small areas such as a city or county their own entire frequency spectrums.

And that, Stevens says, could reduce the need for vehicles, trains and airplanes, since much business that now requires face-to-face communications could be done by lasers and holograms beamed from the space antenna. "I would much rather travel at the speed of light than the speed of sound," he says.

Stevens has proposed his idea to Dupont, which has expressed interest. "Cheap communications is a commodity everyone wants more of," he says. *–Ken R. Wells*

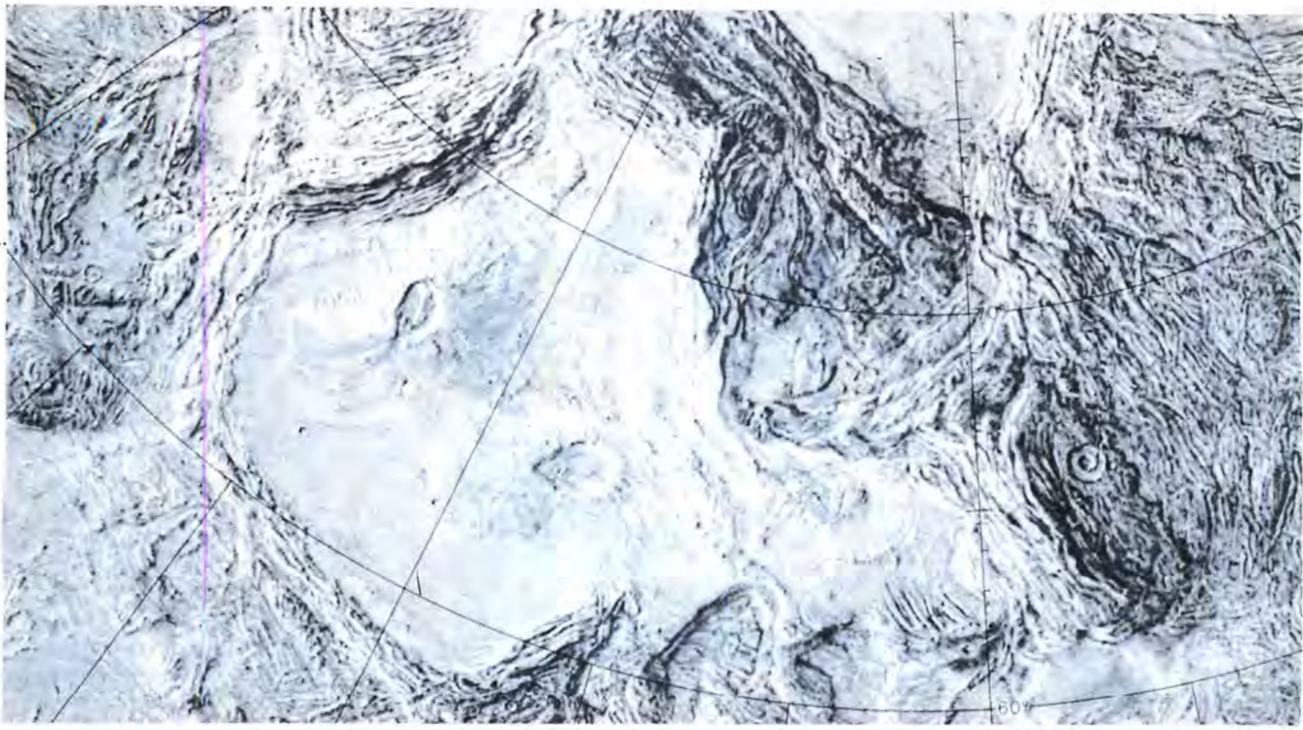
COMING SOON TO A LIVING ROOM NEAR YOU

Not since the 1960s, when *The Jetsons, Star Trek* and *Lost in Space* left the airwaves, has space had a star on its dressing room door. But now that network executives have worn out the urban workplace, the police station, the courtroom and the plaid-couch-in-the-living-room as settings, space may again become a backdrop for sitcoms and TV dramas.

The Challenger, tentatively scheduled to air as a three-hour movie on ABC in February, deals with the people and events leading up to the January 1986 space shuttle explosion. Starring Karen Allen as Christa McAuliffe and Barry Bostwick as commander Dick Scobee, the movie follows the seven Challenger astronauts and their families, and shows the behind-the-scenes pressures and problems that beset the launch. Peter Boyle appears as Roger Boisjoly, the Morton Thiokol engineer who argued against the launch, while Lane Smith (who recently played Richard Nixon) portrays Larry Mulloy, a NASA manager who argued for it. The space agency allowed portions of the movie to be shot on location at the Johnson Space Center in Houston, after reportedly being assuaged that the story would be based on fact and not be overly sensationalized.

CAPITAL CITIES/ABC, INC.

***The Challenger's* Bostwick, Allen and Brian Kerwin, as members of the ill-fated shuttle crew.**



U.S. GEOLOGICAL SURVEY

The continent of Ishtar, shown here in a section of a new Venus map produced by U.S. and Soviet scientists, will be revealed in even more detail when Magellan's radar instrument begins mapping the veiled planet next August.

The producers of "Plymouth" also call their Moon-based space drama "science fact, not science fiction." The two-hour pilot, being produced by Walt Disney Television in conjunction with Rai Television and ABC, concerns the first colony of Earthlings living on the Moon. After toxic gas released in an industrial accident makes a town in the Pacific Northwest uninhabitable, the company responsible for the mishap offers the community of 250 the chance to be the first pioneers to live on the Moon. Publicists for "Plymouth" claim that every detail–from the lunar landscape to the hardware–will be made to look authentic, and will be based on technology available today. The show's developers, who begin production on the pilot in 1990, hope it will lead to an hour-long weekly series.

What you probably *won't* get to see is a situation comedy called "Mars: Base One," which was unsuccessfully pitched to CBS for its Fall 1989 lineup. Produced by Dan Aykroyd and Edward K. Milkis, the show takes place on Mars nearly 100 years in the future, focusing on a family that lives in a community of 10,000 people. The pilot's developers say it's "like an uprooted Cosby family," where the Mars setting offers opportunities for novel plot twists. But even though a pilot episode was filmed, CBS dropped the ball and declined to air the series, which apparently didn't appeal to the right audience as the network struggles to hold on to its diminishing market share.

–Kathleen A. McCarthy

A MAP FOR MAGELLAN

The scientists who will guide the Magellan spacecraft during its upcoming orbital tour of Venus now have a road map for the trip, thanks to collaboration between scientists in the United States and the Soviet Union. For many years, Soviet planetary scientists have participated in informal exchanges of data with their American counterparts. Then the Reagan White House, after some hesitation, okayed the creation of the U.S./U.S.S.R. Joint Working Group for Solar System Exploration, co-chaired by NASA Headquarters and the Vernadsky Institute in Moscow. One product of that agreement was an airbrushed relief map of much of Venus' northern hemisphere, produced by the U.S. Geologic Survey.

The only way to see beneath Venus' dense, perpetual cloud cover is with radar. The new map is based on radar images from NASA's Pioneer Venus Orbiter, the Arecibo radio telescope in Puerto Rico and the Soviet Venera 15 and 16 spacecraft, which went into orbit around Venus in 1983. Together, they revealed a planet dotted with volcanoes, wrinkled by ridges and vast mountain ranges, and relatively free of craters.

Shown in this detail from the map is Ishtar Terra, a continent the size of Australia centered at roughly 20 degrees west and 65 degrees north. The western part of Ishtar is a vast plateau called Lakshmi Planum, some 1,300 miles across. Within the plateau are two huge volcanic craters, Colette (left) and Sacajawea (right). Surrounding Lakshmi Planum are rugged mountain ranges, including the towering Maxwell Montes to the east, which rise more than seven miles above Venus' mean surface.

As detailed as it is, this map will seem crude after Magellan surveys Venus, beginning this summer: that spacecraft's radar images should reveal features as small as 820-980 feet across.

–Andrew Chaikin

ROBOTIC ROCKHOUNDS

When it comes time to explore the surfaces of distant planets, there may be a shortage of trained fieldworkers with rock bags and hammers at the ready. So researchers at the University of New Mexico at Albuquerque are trying to hammer out the

NOTES FROM EARTH

YES!

The verdict is in. Of the 704 people who answered our 900-number phone-in question last May and June, 94 percent said yes, NASA should resume its "Spaceflight Participant Program" to send ordinary citizens into space.

As for our written survey on space tourism, 84 percent thought a commercial, passenger-carrying module should be allowed in the cargo bay of the space shuttle (provided it paid for itself), while 16 percent said it would be ill-advised to send everyday tourists on the shuttle.

And in case you had any doubts, our readers–almost unanimously–want to go into space. A whopping 99 percent were ready to make the trip, with most people willing to pay between $5,000 and $20,000 for the privilege. While some thought a ride into orbit would be worth millions, an equal number would pay only what it

presently costs to buy an airline ticket.

What would be the main attraction of a short trip into space? Just being there, according to many of the people who wrote in. Viewing the Earth from orbit was the single most popular answer; the experience of seeing our home as it really is, a small blue and white sphere floating through the deep blackness of space, would be both spiritually and emotionally fulfilling to many of those who responded. Others looked forward to the launch, the fun of weightlessness, even the fame.

Nor did our readers demand absolute safety. When asked what they would consider an acceptable level of risk to make the trip into space (on a scale of 1 to 5, with 1 equal to airplane travel and 5 equal to armed combat), 8 percent felt that airplane travel was risky enough; 16 percent chose a risk factor of 2; 35 percent were in the middle of the road; 21 percent were almost ready for armed combat, and 20 percent, brave souls, would face a Panzer division to explore the final frontier for themselves.

Thanks to all those who took the time to answer our decidedly unscientific poll. We'll pass the word on to NASA and to all other interested parties.

best robot for the job. The result is the "teleprospector"– 100 pounds of pretend geologist.

According to Gregory P. Starr, associate professor of Mechanical Engineering, the idea for the extraterrestrial prospector came from a collaborator in the geology department, Jeffrey Taylor. The resulting three-wheel, steerable prototype, no larger than a typical riding lawn mower and named "Shashk" (Navaho for "messenger"), is currently being tested at the university.

With development studies funded by NASA's Office of Exploration, the telerobotic field geologist would handle the repetitive aspects of rock sample collection. The robot's designers currently are working on the problem of time delays in sending instructions to the teleprospector, while they try to determine how much intelligence to build in so that it can perform its mission. A second phase of the study will concentrate on outfitting the robot with the proper geologic tools, such as a gripper to acquire rock samples, a drill to take core samples and an arm to break off rock from outcrops.

"No other robot has been designed to break things," says Starr. "Robots just can't impart such energy." But the New Mexico team hopes to solve that problem, and someday to see hundreds of automatic geologists roaming the landscapes of the Moon or Mars, searching for a motherlode.

–Patricia Barnes-Svarney

OFF THE WALLS

The tiny motions caused when a space vehicle fires its thrusters or deploys a payload can ruin the recipe for a space chef cooking with an onboard oven. It's not failed soufflés that have space station Freedom's design engineers concerned, however: it's metals, ceramics and other materials manufactured in microgravity.

"Theoretically, in space you have zero gravity," explains Tom Crabb, Vice President of Orbital Technologies Corporation (ORBITEC) in Madison, Wisconsin. "But there are accelerations that the shuttle experiences, so particles do drift within the vehicle."

That drifting may be fine for astronauts, who can push off a cabin wall if they're jostled, but delicate materials processing samples can't be touched while they're heating, even by the walls of their containers.

"The samples have to be kept suspended," Crabb says, "but without contacting the containers, because that could influence how the crystals form." The answer, he says, is to either have the samples heating within a big volume of space, which is difficult aboard the shuttle, or be able to contain them somehow within a small space. ORBITEC is looking at the second approach, testing sonic pumps that would use sound waves to push air or a gas that would keep the particles suspended in the furnace.

It will be about two more years, predicts president Eric Rice, before the company is ready to bring their space oven to market. The three-man firm does have a lab prototype, however, and anticipates testing it aboard a KC-135 weightlessness training aircraft soon. They expect the device could help reduce some of the restrictions on materials processing onboard the space station.

"The farther from the center of gravity of [a spacecraft], the worse the drift effect is," says Crabb. This type of containerless processing could allow space chefs to cook even when they aren't in the quiet zone near *Freedom's* center of gravity. *–Maura Mackowski*

MISSION FILE

STS-34

LAUNCH:
12:53 p.m. EDT, October 18, 1989 Pad 39B, Kennedy Space Center, Florida
LANDING:
9:32 a.m. PDT, October 23, 1989 Edwards Air Force Base, California
ORBITER:
Atlantis
ALTITUDE:
160-178 nautical miles
CREW:
Donald E. Williams, Commander
Michael J. McCulley, Pilot
Franklin R. Chang-Diaz, Shannon W. Lucid, Ellen S. Baker, Mission Specialists
PRIMARY PAYLOAD:
Galileo Jupiter spacecraft
OTHER PAYLOADS:
Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument
Polymer Morphology experiment
Mesoscale Lightning experiment
Growth Hormone Concentrations and Distribution in Plants experiment
Zero-g Growth of Ice Crystals (student experiment)
IMAX camera
Sensor Technology experiment

Each time Atlantis and the Galileo spacecraft seemed ready to set out on the STS-34 mission, there was one more hoop to jump through. Two days before the planned launch, anti-nuclear activists took NASA to court over Galileo's plutonium-powered generators, then vowed to "sit on the launch pad" when their legal battle was lost. Atlantis wasn't leaving on time, anyway; first a faulty engine computer, then two days of capricious Cape Canaveral weather, stalled the shuttle's liftoff.

But in the early afternoon of October 18, the protesters were nowhere to be found, the cloud-flecked Florida skies were bright and sunny ...and a new era in planetary exploration was about to begin.

DAY 1

After a quick switch in trans-Atlantic abort sites due to weather, Atlantis made the familiar eight-and-a-half-minute climb into orbit. Only a failed maneuvering engine controller marred an otherwise faultless ascent.

Atlantis' five astronauts spent most of the afternoon performing equipment and communications checks and verifying that Galileo and its Inertial Upper Stage (IUS) booster were ready for flight. As the orbiter passed over Brownsville, Texas, on its fifth orbit, a spring mechanism delicately nudged the 39,000-pound spacecraft/booster combo out of the payload bay; two hours and two successful IUS engine firings later, Galileo was bound for Venus on the first leg of its roundabout trip to Jupiter.

The astronauts worked with the mission's secondary payloads as they wound down their first day in space. Mission specialists Chang-Diaz and Lucid set up 3M's Polymer Morphology apparatus, an experiment designed to examine the effect of zero-g on melt processing of several industrial polymers. The crew also worked with Mission Control to troubleshoot a problem with Atlantis' cooling system, which had automatically switched itself from low to high shortly after the spaceliner reached orbit. The anomaly was tentatively blamed on excess heat from the nuclear generators aboard the now-departed Galileo probe.

DAY 2

Two hours after awakening to "Hail, Purdue" (Atlantis' commander Williams and pilot McCulley both are Purdue graduates), the astronauts settled in for a full workload of in-space experiments. Chang-Diaz activated the SSBUV instrument, which NASA developed to measure the amount and vertical distribution of ozone in Earth's atmosphere. The readings obtained during STS-34, as Atlantis and two orbiting U.S. weather satellites crossed over the same region within a one-hour period, will be used to calibrate older, less reliable instruments on the satellites.

Earth's surface also was the target of the Mesoscale Lightning experiment. As the orbiter passed through darkness, video cameras mounted in the payload bay sent back spectacular images of blossoming lightning flashes that looked remarkably like a World War II nighttime bombing mission. The crew also used a 70 millimeter IMAX movie camera to photograph the sunlit side of the globe; the scenes will be incorporated into two future films that will play at the National Air and Space Museum in Washington, D.C., as well as other IMAX-equipped theaters.

Williams, Baker, Chang-Diaz, Lucid and McCulley pose for a group portrait onboard Atlantis.

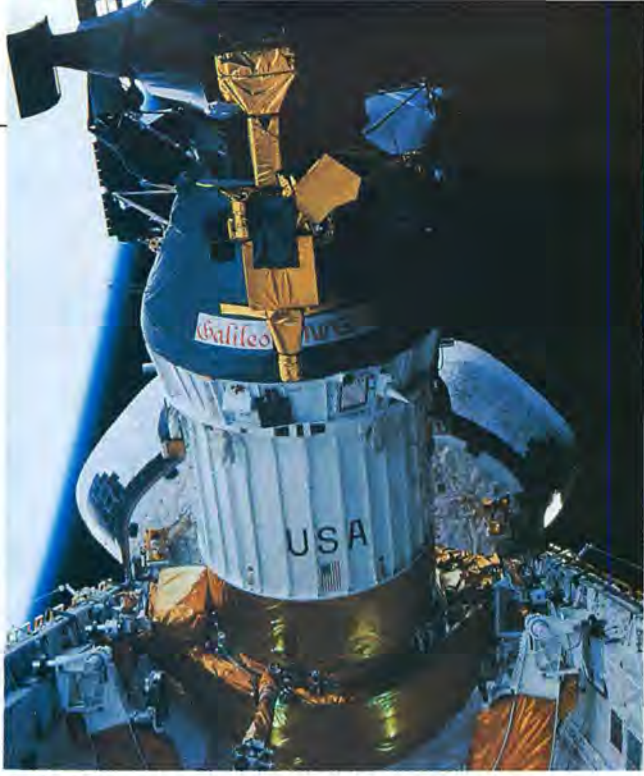
In one of the flight's medical tests, mission specialist Baker strapped on a pair of special swimming goggles, through which Chang-Diaz photographed her retinal blood vessels. Researchers hope to determine if those vessels reflect changes in the brain that can lead to the onset of space sickness. "Our flight surgeons say the look inside Ellen's eye was excellent," radioed astronaut Mike Baker (no relation), joking that "they'd like her to set up an appointment with the ophthalmologist when she gets back."

DAY 3

Atlantis' astronauts spent a "routine" day in orbit, performing sample runs in the Polymer Morphology experiment and taking data with the SSBUV mounted in "Getaway Special" canisters attached to the orbiter's cargo bay.

One device *not* functioning according to plan was the student experiment to study the growth of ice crystals in microgravity. When the apparatus had been activated the previous day it had formed a "slug" of ice on its cooling plate. Shuttle commander Williams and mission specialist Shannon Lucid induced the mechanism to start growing ice crystals, using what NASA whimsically called the "direct approach": They reloaded the experiment with water and simply shook it a few times.

The crew turned Atlantis into an orbiting video studio, sending back television views of Mike McCulley and Franklin Chang-Diaz wrestling with IMAX film magazines inside a light-proof reloading bag, as well as scenes of paper stacking operations at the orbiter's TAGS super-fax machine. Using the IMAX camera, the astronauts shot vistas of Earth terrain as varied as Greece, the deserts of Saudi Arabia and Mt. Fuji in Japan.



Galileo prepares to escape its troubled past and head toward Jupiter.

DAY 4

With all of Atlantis' systems and payloads humming along smoothly, the spaceplane's crew faced a rather undemanding Saturday schedule that allowed for some typical "tourist" activities. Early in the day, the astronauts marveled at a stunning display of the Aurora Australis (Southern Lights) caused by the interaction of charged particles from the Sun and Earth's magnetic field.

There also was time for a little public relations gimmickry. Costa Rican president Oscar Arias placed a pre-arranged call to Atlantis for a chat in Spanish with mission specialist Chang-Diaz, a native of Costa Rica. He greeted the astronauts in turn, congratulating them on a successful mission and joking with shuttle commander Williams that he was lucky "not to have any economists or political scientists on board."

Chang-Diaz and Williams had more serious duties as well, performing the final SSBUV experiments, then commanding the instrument to calibrate its data and shut itself down. Ellen Baker continued a medical study aimed at determining how well the anti-motion sickness drugs scopolamine and dextroamphetamine perform in orbit.

The astronauts themselves couldn't do anything about the day's only "problem." The prospect of high winds at Edwards AFB for Monday's planned landing time forced Mission Control to order Atlantis down earlier than scheduled, so the crew turned in 90 minutes early to adjust their work/sleep cycle.

DAY 5

Williams, McCulley, Lucid, Chang-Diaz and Baker had little to do on their fifth day in orbit expect prepare for their return to Earth. Atlantis' commander and pilot checked the orbiter's flight control systems and fired their reaction control system maneuvering engines. The other crew members busied themselves storing equipment in the craft's middeck lockers.

Lucid and Baker closed out the Growth Hormone Concentration and Distribution in Plants experiment by freezing two of four canisters containing corn plant seeds. Researchers hoped to learn more about the effects of zero-g on auxin, a growth hormone, by comparing the frozen specimens with those allowed to grow during the entire mission.

In an interview with Cable News Network, the astronauts spoke eloquently of the changed perspective on our home planet spaceflight had given them. "The world as we know it is a very fragile place," Don Williams explained. "From this point of view, it's very obvious that's the case—and we need to take care of it."

DAY 5

Awakened by Steve Miller's recording *Fly Like an Eagle,"* the STS-34 astronauts readied themselves for the long glide to the dry lakebed in the California desert.

Atlantis' Orbital Maneuvering System rockets rumbled to life as the craft rushed backward over the island of Madagascar. The decision to land two orbits early meant that Williams and McCulley had to command the 97-ton spaceliner to perform a wider- than-normal banking maneuver after the blazing reentry though Earth's atmosphere in order to line up properly over the California coast.

A weekday crowd of 20,000 shuttlewatchers heard the familiar double sonic boom as Atlantis dropped below the speed of sound. Williams and McCulley brought the spaceplane in for a perfect touchdown, abandoning the planned nosewheel steering and braking tests because of the potential for gusty winds.

Capsule Communicator Ken Cameron in Houston summed up the elation of NASA officials in his message to Atlantis' crew: "Congratulations on an outstanding mission. You've extended the shuttle's reach to the outer planets."

At that moment, Galileo was about a million miles away, zooming flawlessly along on its voyage to Jupiter.

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E S S A Y

BY JAMES E. OBERG

The Soviet space program, once the object of hero worship, suddenly finds itself with a lot of explaining to do.

TROUBLE IN STAR CITY

Twenty years apart, I made two visits to the Soviet Union's main space museum in Moscow. The first was in 1968, at a time when the Space Race was in full swing. Russia appeared to be winning, and the bloom was on the rose. At the Park of Economic Achievements in northern Moscow, the Kosmos Pavilion was bright with the summer sunshine and the smiling faces of thousands who thronged past the rows of futuristic space machines. This was their future, worth sacrificing for, and they knew the world envied them.

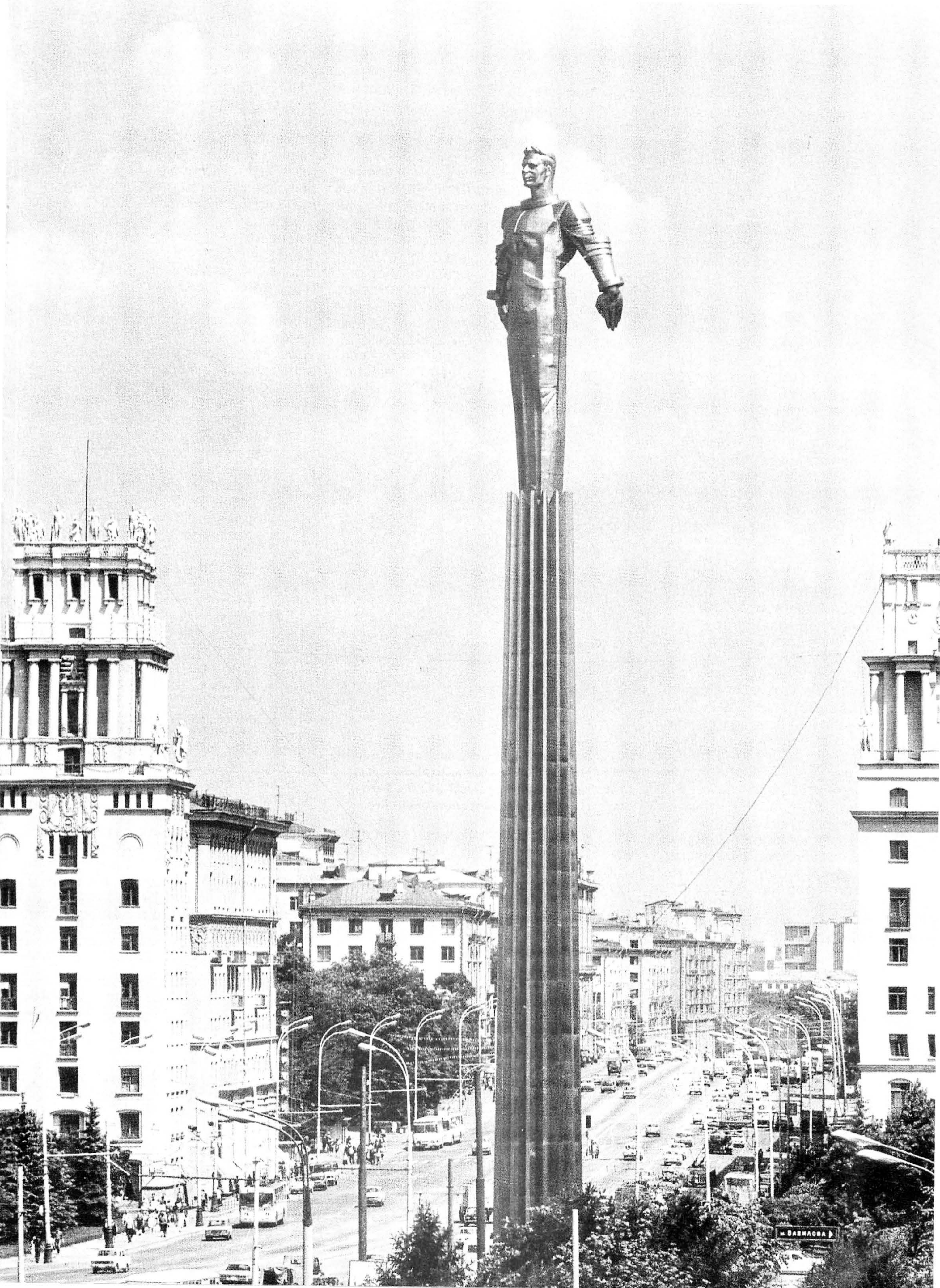
In 1989, I hiked through early spring slush and late afternoon gloom to revisit the same shrine. The long, dingy hall had the aura of a forgotten tomb. The colossal rotunda area was cordoned off, its collapsing central dome a hazard to stragglers who wandered amidst the dust and rust, seeking nostalgic glories. Through a double door, a small side hall offered a colorful, brightly lit exhibit on flying saucers and ESP. Grim-faced out- of-town Russian tourists broke into grins of glee as they entered the world of the paranormal, leaving the disappointments of reality behind.

APN

The same space program that in decades past produced the triumphs of Sputnik and Yuri Gagarin is currently undergoing a major shift in the way it is viewed by the Soviet people. Once demi-gods, space heroes have been brought low in the public's estimation. Their achievements, once a source of infinite pride, now elicit resentment. While a statue of Gagarin at the cosmonaut training center at Star City (left) is always graced with flowers left by cosmonaut colleagues or by respectful official visitors, another statue (opposite) located on a major Moscow thoroughfare–an idealized human figure with sweeping lines representing unbounded flight–was derided by one cynical Russian observer as the triumph of socialism, "Man turned into machine." There never are any flowers.

How well the Soviet space program

NOVOSTI



ВАВИЛОВА

can survive this de-mythologizing is as yet unpredictable. International critics have long regarded the Soviet Union as a third world nation with pockets of isolated high technology. On the world stage, the sprawling country would amount to little were it nor for its nuclear weapons, Olympic athletes, ballet stars–and space vehicles. The current widespread opposition to space activities has therefore baffled many foreign observers.

Space, after all, has been an authentic subject for national pride. In space, the Russians were indeed first, particularly in the late 1950s, when the West ate their dust year after glorious year. Here, at least, communist dogma was becoming true, as the self-styled most advanced society on Earth led humanity's expansion into the Universe. The ideological value of space preeminence was profound, and official Soviet art reflected this para-religious theme: paintings of space heroes were done in styles slavishly derivative of Florentine triptychs and cathedral bas-reliefs.

True, the multiple space race losses of the 1970s–when Americans beat the Soviets to the Moon, to a space station, to a robot landing on Mars, and finally to a reusable space shuttle–did disconcert those better informed among the general public. A few isolated dissidents cried out for "Bread, not sputniks!" But the state-run news media were consistently upbeat: Spaceflight was good for Russia, and nobody thought differently.

"For decades, cosmonautics was considered almost a sacred cow of the economy," wrote *Izvestiya*'s space correspondent Sergey Leskov last March. "To argue about the cost of supporting it was considered wrong and unpatriotic."

Recently, however, despite record-setting flights on the Mir space station and successful tests of the Energia super-booster and a prototype space shuttle, the bubble of public approval has burst. Suddenly there are arguments everywhere.

The vigorously pro-Perestroika weekly *Arguments and Facts* published a letter last June from a group of health workers in Shakhty, a mining city in the Ukraine.

"When will all this 'peaceful exploration of space' come to an end?" they demanded. "It is impossible to remain undisturbed seeing people's money go down the drain! Come down from the heavens to our sinful earth! There is no sugar, soap, drugs... Shame! Mother Russia has remained as backward as it used to be!"

On Cosmonautics Day, the anniversary of Gagarin's first flight, the labor daily *TRUD* reported that its mail was ten to one in favor of sharp cutbacks in space expenditures. Some readers called for a complete cutoff of funds, asking "Why do we need a space program if we don't have sufficient means for priority needs here on Earth, and if millions of people living below the poverty line cannot make ends meet?"

Those letters echo complaints heard widely during the national election campaigns last March. Maverick Moscow politician Boris Yeltsin was the loudest, but not the most extreme: "I'm not saying we should abandon space research, just stretch it out," he explained, calling for a five- to seven-year delay in many major projects. Yeltsin swept 90 percent of the vote.

On the TV program "Moscow News" in August, during a candid roundtable discussion on the value of space exploration, science editor Leonard Nikishin offered a credible explanation for the vehemence of the negative outbursts: "Where do these extreme views come from–the total, angry denial of the need for 'useless' spending on space? I believe that, not least of all, this is a consequence of well-nigh universal irritation over the hullabaloo of many years about our 'space victories.' But the people lived in a different world. They were short of too many good things of life to take these victories close to heart."

Images of past glory, such as this adoring triptych of Yuri Gagarin (above), pale as expensive projects like the Buran shuttle (opposite) come under fire.

AVIATION AND COSMONAUTICS MAGAZINE

SPACE COMMERCE CORPORATION

Not all the criticism has come from outside. Joining the chorus of dissent have been several voices from within the Soviet space hierarchy. Cosmonaut training director Vladimir Shatalov, a three-time space veteran, has bemoaned the lack of long-range planning and the absence of industrial follow-through to space research. Space scientists, after two Phobos probes failed to complete their missions to the moons of Mars last year, blamed mismanagement in the Soviet space bureaucracy.

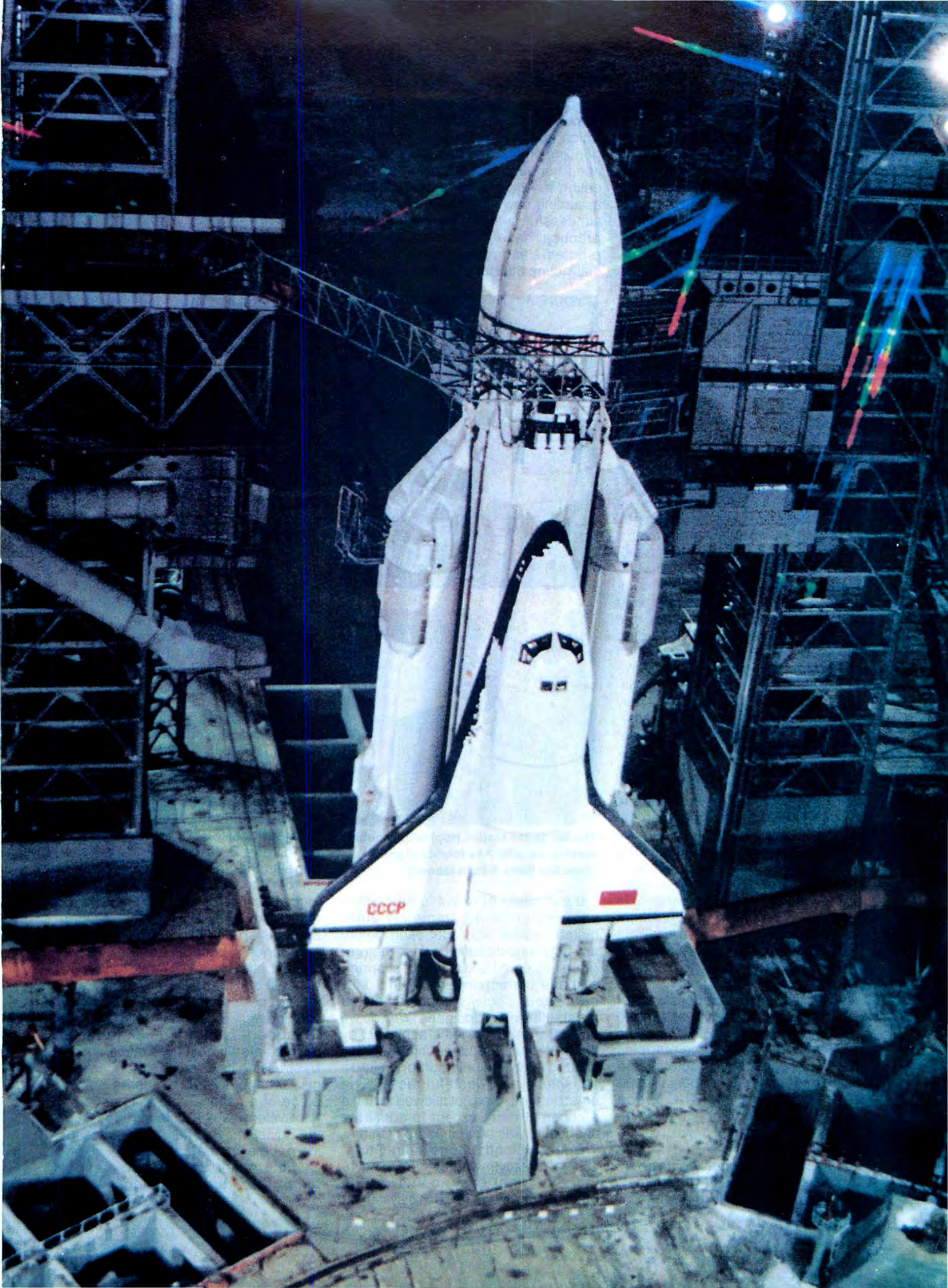
Ironically, it is the scientists who have become the target of mis-aimed public anger. For decades, the real purpose of space shots in the Kosmos series had been camouflaged by deceptive announcements about "scientific instruments for the exploration of outer space," when most actually were military in nature–spy satellites, weapons control systems or actual weapons tests. Many others were for civil applications such as weather and navigation, or for testing prototype hardware. Only a handful were really for science.

Yet the Soviet public came to perceive scientists as draining the public treasury out of idle curiosity, with no practical benefits to show. For their part, the scientists couldn't explain that most satellites called "scientific" were really for the military, since that was–and even under Glasnost, still remains–a state secret.

Leading spacecraft designer Konstantin Feoktistov, himself a space traveler in 1964, said in the "Moscow News" roundtable: "A mere one percent of [annual expenditures] goes for 'strictly' scientific research by space specialists." Yet, Feoktistov sadly observed, "In the eyes of ordinary people it has turned into a devourer of incalculable sums."

Official unwillingness to admit the exact amount of space expenditures has itself caused mistrust. Even *Izvestiya* complained that Soviet space budgets are not published, which negatively affects public attitudes toward space. "When [the sum] is not named, you inevitably imagine astronomic appropriations which, when you look at empty store counters, you cannot help wanting to cut," the paper editorialized.

How much do the "incalculable sums" spent on space programs amount to? General M. Moiseyev, chief of staff of Soviet armed forces, told


СССР

Pravda in June that the Soviet Union allocated 6.9 billion rubles to all space expenditures in 1989, of which 3.9 billion were for military, 1.7 for research and 1.3 for the Buran space shuttle. In the past four years, the manned Mir/Soyuz program has allegedly cost only 1.47 billion rubles, while the multimodular Mir space station has cost 1.7 billion rubles alone over the course of 13 years. According to Feoktistov, "During the 30 years of manned space flights we have spent about six billion rubles on them."

But these figures seem suspiciously low, even at the official exchange rate of 0.6 rubles to a dollar (the black market rate is about eight to ten rubles to the dollar). This should be hardly surprising, since the primary intent in publishing them was to show the public that the space program doesn't cost that much after all.

Any comparison of American and Soviet space budgets must take into account that Soviet workers are paid far less than their American counterparts. By keeping salaries low, the government squeezes enormous amounts of rubles for its space budget out of workers. Another factor in any budget comparison is hidden costs. The operating costs of many Soviet ministries that support the space industry—including those responsible for the acquisition and pre-processing of materials—have their own budgets, which are an invisible subsidy to the space effort. It may be that the Soviet economy is so disorganized that no one, not even Soviet leaders, knows how much is really being spent on space activity. But it is probably twice the official tally, possibly even more. The economic burden is therefore far higher than the published figures admit, and the public's intuition is more accurate than the government's bookkeeping.

The other side of the ledger—economic benefits to those on Earth—has been equally grim. The government lists miraculous "spinoff" products from the space program, which, ordinary Russians realize all too bitterly, nobody can buy.

So, in its hunger for a better standard of living, the Soviet public has made space spending a target of ire. At a time when the Gorbachev regime grapples with serious economic problems, the space program seems especially vulnerable. Major cuts to the space budget would give Gorbachev some breathing room, and would be immensely popular.

But where could the cuts come from? With spokesmen boasting that satellites augment the effectiveness of Soviet armed forces by 150 to 200 percent, military space programs seem immune. So do applications satellites, which apparently are able to eke out genuine profits. Space science doesn't spend enough to save much by canceling it. And the Mir space station—assuming new modules are added on successfully—also can make a good practical case for funding. One last program stands out as an ideal sacrificial victim: the Buran space shuttle.

TASS/SOVFOTO

TASS/SOVFOTO

The Mir space station (top) will probably survive, despite the protests of politicians like Boris Yeltsin (above).

Buran made its debut in 1988 with a successful—and completely automated—orbital flight. But even before any cosmonauts have flown it, the program has come under fire. Last spring a space correspondent for the daily newspaper *Socialist Industry,* asked the shuttle's chief designer, "Why do we need Buran? The goals achieved by this truly marvelous machine are still unseen. Aren't we being dragged into a senseless and wasteful race?" The chief designer was not allowed to make a coherent reply, except to admit the spaceship was a bit ahead of its time.

Space scientist Konstantin Gringauz, in *Izvestiya,* was even more cynical: "It is not easy to answer the question of why we need this system at this particular time.... In my opinion, it cannot be ruled out that the main reason for the creation of the Energiya-Buran system was the desire of the [ministry] to assert itself, and not the real needs of the country and of science."

Other space scientists see Buran as the enemy. Roald Sagdeyev, formerly head of the Soviet space science establishment and a leading adviser to the Gorbachev regime, told *Moscow News* that the entire Buran program was a mistake: "Even today, Buran consumes the lion's share of expenses in the space budget...but it seems to me that even the crudest economic estimates of the necessary missions give an unambiguous answer. I am all in favor of disposable syringes, and against reusable Buran."

In the same interview, manned spacecraft designer Feoktistov concurred. He mocked the idea of using Buran to recover precious satellites. "Any, even the most sophisticated spacecraft, is far cheaper than one flight of Buran...[yet] we have stubbornly continued spending money on this hopeless affair."

Notably lacking in official responses to this groundswell of disaffection are the ideological pronouncements and appeals to national pride and glory. Instead, officials turn to bottom-line cost accounting of profits and losses. Spaceflight, they say, is supposed to show a profit.

Since 1975, according to Semyonov and other space officials, about 14 billion rubles have been spent on the entire Buran program. At the same time, developing Buran supposedly led to more than 400 major technological breakthroughs, with revolutionary implications for Soviet industry and world trade. But in order to realize those benefits the Soviets must overcome a system that has shown itself immune to innovation and to efficient use of technology. And they must correct misconceptions about American space costs and benefits, such as the widespread Soviet belief that NASA fully recouped the cost of the Apollo program by selling space technology patents to private industry.

Supporters of the Buran program have painted themselves into a corner by stressing its value as a pathfinder of new technology rather than a crucial piece of a national space transportation system—which it clearly isn't, since the Soviets have other means of sending people and cargo into orbit. Ironically, the major economic benefit of Buran may lie in the scientists and

continued on page 54

Is space travel for average people too far in the future ?
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January 1, 1990

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We encourage you to join us. Registration fee is only $25 per year. When you join our network, you will receive an attractive, sometimes amusing or serious, but always interesting, quarterly newsletter. You will also receive a giant poster and a beautiful, long lasting personalized certificate, stipulating that you are part of a network dedicated to space travel. Finally, we can make no promises, but if ever the project were to become a reality, a draw would be organized in which you would be included. The winners would travel in space. Tickets would be for two people.

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Robert Giguère

Robert Giguère
Project Coordinator
SPACE TRAVEL NETWORK

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Vice President Dan Quayle, Chairman, National Space Council

A Universe of Opportunities

Humans have walked on the Moon, and machines built by humans have visited all but one of the known planets. Earth is patrolled by remote sensing and weather satellites that constantly take the planet's pulse. Our voices, pictures and data travel almost instantly around the world, thanks to a constellation of communications satellites in Earth orbit.

Where do we go from here?

You've probably asked that question many times if you think an aerospace career is for you. Well, there's good news: The most ingenious space programs are barely underway, and the boldest explorations have yet to begin.

In the next decade, sophisticated robots will return to Mars, Venus, Jupiter and Saturn for extended stays. New space-based observatories—the Hubble Space Telescope, the Gamma Ray Observatory, the Advanced X-ray Astrophysics Facility and the Space Infra-Red Telescope Facility—will revolutionize astronomy and make the entire universe a familiar neighborhood.

Closer to home, the international Mission to Planet Earth will open a new era of space-based investigations of our own world. Orbiting spacecraft equipped with a battery of scientific instruments will study the complex interaction of land, sea and atmosphere, returning vast amounts of data that will challenge our fastest computers and improve our understanding of Earth's climate.

Launching payloads into orbit for profit will continue to be a booming industry in the 1990s. Large companies such as Arianespace, McDonnell Douglas, Martin Marietta and General Dynamics will get most of their business by launching the next generation of communications satellites. While the international Intelsat consortium will continue to dominate world telecommunications, private entities such as PanAmSat, GTE Spacenet and Geostar will attempt to capture specialty markets.

There also will be plenty of smaller satellites and payloads to go around. Among the competitors for that share of the space marketplace will be the Scout launcher built by LTV Corporation, the American Rocket Company's Industrial Launch Vehicle, the Conestoga series of launchers planned by Space Services, Inc., and the Pegasus rocket under development by Orbital Sciences Corp.

In the 1990s the space shuttle will continue to be NASA's workhorse vehicle for hauling people and cargo into Earth orbit, with more than 60 missions on the space agency's manifest through 1995 alone. At least 19 of those flights will carry either a Spacelab module or a commercial Spacehab facility into orbit for conducting experiments ranging from astronomy to life sciences.

Then, in 1995, shuttle crews will begin to construct a permanent orbiting base in the sky—space station Freedom. Astronauts aboard Freedom will perform virtually every space activity that humans can conceive of. The station will supplant the shuttle as an orbiting laboratory for microgravity experiments in fluid dynamics, production of new and improved metals and alloys, and biotechnology research. Crews will investigate the medical effects of long-duration stays in zero-g and test new robotic technology.

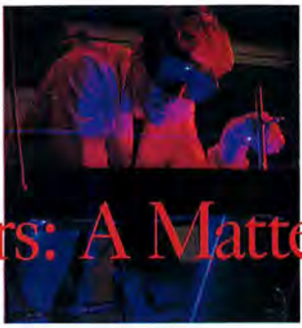
Even as the space station takes shape, teams of scientists and engineers will be planning new ways to get humans and their machines into orbit. One proposed solution to the current high cost of space travel is the NASA/Air Force Advanced Launch System. A serious competitor to ALS may be the Shuttle-C design, which couples the shuttle's proven solid rocket booster technology with a cargo-carrying version of the orbiter's fuselage. Astronauts themselves may ride into space aboard a derivative of the National Aero-Space Plane, a single-stage-to-orbit vehicle also being conceived by NASA and the Air Force.

And, for the first time in twenty years, America is looking beyond Earth orbit to a grand new adventure in space. Early in the 21st Century, we intend to return to the Moon and voyage off to the planet Mars. The specifics have yet to be worked out, but the effort is likely to dwarf the Apollo program by comparison.

Our first lunar base will be a spartan outpost where, in addition to venturing outside to conduct forays themselves, astronauts will probably control an army of versatile robotic workers and explorers. Meanwhile, automated spacecraft will probe Mars to pave the way for the first human visitors, who will arrive sometime between 2010 and 2020. Whether it's a solitary ship or an international fleet adorned with many national symbols, humans will have begun their slow but inevitable expansion to the other planets of the Solar System.

What does all this activity mean for you? Whether your interest is in astronomy or law, social sciences or humanities, computer systems or engineering, you'll be able to find your niche as we take our first halting steps on a path that will lead to the stars. Even if hard science isn't your game, the exciting and innovative projects planned for the next thirty years are so varied, you'll have to look hard to find a field that *doesn't* have some application to space.

In short, there's a universe of opportunities waiting for you. At last, the sky is no longer the limit.



Space Careers: A Matter of Degree

RON FRANKLIN

For most people, choosing the right school and the right degree is the first step on the road to a career in aerospace. Remember, though, that you don't have to restrict yourself to pursuing a degree that has "space" or "astro" in its title. Most technical degrees will ensure you'll be considered by aerospace industry and government recruiters. For example, here are just a few of the disciplines NASA recommends for potential aerospace technologists:

- Biomedical Engineering
- Ceramics
- Chemistry
- Industrial Engineering
- Materials Science
- Metallurgy
- Optical Engineering
- Oceanography

Also, don't ignore non-technical fields such as finance, communications, marketing, management and data processing. Any aerospace firm, whether government or private, can function only when it has qualified people who keep the records, pay the bills and keep its organizational structure humming along. And most large companies also need lawyers, writers and artists (where do you think those paintings of NASA's yet-to-be-built space station come from?)

Remember, too, that stellar academic achievements won't guarantee you a place in space. Good grades are important; anything less than a 3.0 (out of 4.0) is likely to put you pretty far back in the pack with a prospective employer. But both NASA and the private sector also evaluate what you've done *outside* the classroom and how you come across as a prospective employee.

WHAT SCHOOL SHOULD I CHOOSE?

Although just about any accredited college or university can get you started on the road to a space career, some schools have special programs focused on space science and technology.

In 1989, NASA selected 17 universities and consortia as designated "Space Grant Colleges," which will receive grants to further their programs in space education and to provide fellowships to undergraduate and graduate students (see list). The agency also helped establish University Space Engineering Research Centers at the following schools in 1988: Penn State, MIT, Rensselaer Polytechnic, North Carolina State at Raleigh/North Carolina Agricultural and Technical State University, and the Universities of Arizona, Cincinnati, Colorado (at Boulder), Idaho and Michigan. These centers stress interdisciplinary space-related research in selected areas—for example, the University of Colorado center concentrates on space construction, while the work at Rensselaer is in robotic systems for space exploration. NASA hopes to establish more centers in coming years.

In cooperation with the Universities Space Research Association, the space agency also sponsors an Advanced Design Program whereby students at selected schools work on advanced mission studies for NASA within the context of their accredited courses. Information on this program is available from USRA, 2525 Bay Area Blvd., Suite 530, Houston, Texas 77058; Phone: (713) 480-5939.

NASA field centers located around the country offer high school, college and graduate students the chance to get

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UNIVERSITY OF WISCONSIN

hands-on work experience while completing their education, through the agency's Cooperative Education Program (contact the personnel office at any of the NASA centers listed on page 14 for more information). Large aerospace companies may also have co-op and internship programs in your area.

New opportunities in space education are cropping up outside NASA as well. While it doesn't yet offer a degree program, the Boston-based International Space University has brought together graduate students and space professionals from around the world for two successful summer study programs, and hopes to have a year-long program, as well as a campus to call home, beginning in 1992. Other schools, like the University of North Dakota, are trying to expand their aerospace departments to become more of a "player" in the field of space education.

USING THE RESOURCE LIST

The following colleges and universities (listed on pp. 5-9) offer degree programs that can be considered specialized space-related disciplines. Of course, most major institutions offer degrees in general areas of science, mathematics and engineering that will open doors for you just as well.

Obtaining information on baccalaureate degree programs usually is as simple as calling or writing the university's admissions office to ask for a copy of the general catalog. Contacting the specific department for information at the undergraduate level won't accomplish much—you'll still receive a catalog.

Working toward an advanced degree is a different matter. The best way to find out if an institution's graduate program is right for your plans is to find someone who has already completed the program. Often they'll be able to "network" you with professors and administrators who can give you specific guidance.

CALTECH

NASA SPACE GRANT COLLEGES/CONSORTIA

Alabama Space Grant Consortium
University of Alabama in Huntsville
University of Alabama, Tuscaloosa
University of Alabama at Birmingham
Alabama A&M University, Normal
Auburn University

Arizona Space Grant College Consortium
University of Arizona, Tucson
Northern Arizona University, Flagstaff
Arizona State University, Tempe

California Space Grant Consortium and Fellowship Program
University of California, Berkeley
University of California at Los Angeles
University of California at San Diego

Colorado Space Grant Consortium
University of Colorado, Boulder
Colorado State University, Fort Collins
University of Colorado, Colorado Springs
Fort Lewis College, Durango
Mesa State College, Grand Junction
University of Southern Colorado, Pueblo

Cornell Space Grant College Consortium
Cornell University, Ithaca, NY
Clarkson University, Potsdam, NY

Florida Space Grant Consortium
University of Florida, Gainesville
Florida State University, Tallahassee
Florida A&M University, Tallahassee
University of Miami

Georgia Institute of Technology Space Grant Consortium
Georgia Institute of Technology, Atlanta
Georgia State University, Atlanta
Clark Atlanta University, Atlanta
Tuskegee University, Ala.

Aerospace Illinois Space Grant Consortium
Illinois Space Institute
University of Illinois, Urbana-Champaign
Illinois Institute of Technology, Chicago
University of Chicago
University of Illinois, Chicago
Northwestern University, Evanston

The Johns Hopkins Space Grant Consortium
The Johns Hopkins University, Baltimore
Space Telescope Science Institute, Baltimore
Morgan State University, Baltimore

Massachusetts Institute of Technology, Cambridge

Michigan Space Grant College Program
University of Michigan, Ann Arbor
Michigan Technological University, Houghton
Saginaw Valley State University, University Center
Wayne State University, Detroit

Ohio Aerospace Institute
University of Akron
Cleveland State University
Ohio State University, Columbus
University of Toledo
Case Western Reserve University, Cleveland
University of Cincinnati
University of Dayton
Ohio University, Athens
Wright State University, Dayton

Pennsylvania State University, University Park

Rocky Mountain Space Grant Consortium
Utah State University, Logan
University of Denver, Colo.
University of Utah, Salt Lake City

Texas Space Grant Consortium
University of Texas, Austin
Texas A&M University, College Station
Baylor University, Waco
Lamar University, Beaumont
UT Health Science Center, Houston
UT Health Science Center, San Antonio
UT Southwestern Medical Center, Dallas
University of Houston
University of Houston at Clear Lake
Texas A&M University at Galveston
Texas A&M University, Kingsville
University of Texas at Arlington
University of Texas at El Paso
University of Texas at San Antonio
University of Texas at Dallas
Texas Southern University, Houston
Texas Christian University, Fort Worth
Rice University, Houston
Prairie View A&M University
Southern Methodist University, Dallas
Texas Technological University, Lubbock

Virginia Space Grant Consortium
University of Virginia, Charlottesville
College of William and Mary, Williamsburg
Virginia Polytechnical Institute and State University, Blacksburg
Hampton University
Old Dominion University, Norfolk

University of Washington, Seattle

Key to Degrees: A = Associate B = Bachelor's M = Master's D = Doctorate W = Work Beyond Doctorate

AEROSPACE/ AERONAUTICAL/ ASTRONAUTICAL ENGINEERING

ALABAMA

Auburn University; B,M,D
Auburn, AL 36849
(205) 826-4000

Community College of the Air Force; A
Maxwell Air Force Base, AL 36112
(205) 293-7847

Tuskegee University; B
Tuskegee, AL 36088
(205) 727-8011

University of Alabama in Huntsville; B,M,D
Huntsville, AL 35899
(205) 895-6120

University of Alabama; B,M,D
Tuscaloosa, AL 35401
(205) 348-6010

ARIZONA

Arizona State University; B,M
Tempe, AZ 86301
(602) 965-3255

Embry-Riddle Aeronautical University: Prescott Campus; B
Prescott, AZ 86301
(602) 778-4130

University of Arizona; B,M,D
Tuscon, AZ 85721
(602) 621-3237

CALIFORNIA

Azusa Pacific University; B
Azusa, CA 91702
(818) 969-3434

California Insititute of Techonology; B,M,D,W
Pasadena, CA 91125
(818) 356-6811

California Polytechnic State University: San Luis Obispo; B
San Luis Obispo, CA 93407
(805) 546-0111

California State Polytechnic University: Pomona; B
Pomona, CA 91768
(714) 869-2000

Merced College
Merced, CA 95348
(209) 384-6000

Northrop University; B,M
Los Angeles, CA 90045
(213) 337-4413

San Bernardino Valley College; A
San Bernardino, CA 92410
(714) 888-6511

San Diego State University; B,M
San Diego, CA 92182
(619) 594-5200

San Jose State University; B
San Jose, CA 95192
(408) 924-1000

Southwestern College; A
Chula Vista, CA 92010
(619) 421-6700

Stanford University; M,D
Stanford, CA 94305
(415) 723-2300

University of California Davis; B,M
Davis, CA 95616
(916) 752-1011

Los Angeles; B,M,D
Los Angeles, CA 90024
(213) 825-4321

University of Southern California; B,M,D
Los Angeles, CA 90089
(213) 743-2311

West Coast University; M
440 Shatto Place
Los Angeles, CA 90020
(213) 487-4433

COLORADO

United States Air Force Academy; B
Colorado Springs, CO 80840
(303) 472-1818

University of Colorado at Boulder; B,M,D
Boulder, CO 80309
(303) 492-0111

CONNECTICUT

University of Connecticut; M,D
Storrs, CT 06269
(203) 486-2000

DISTRICT OF COLUMBIA

George Washington University; M,D
Washington, D.C. 20052
(202) 994-1000

FLORIDA

Embry-Riddle Aeronautical University; B,M
Daytona Beach, FL 32014
(904) 239-6000

Florida Institute Of Technology; B
Melbourne, FL 32901
(407) 768-8000

University of Central Florida; B
Orlando, FL 32816
(407) 275-2000

University of Florida; B,M,D
Gainesville, FL 32611
(904) 392-3261

GEORGIA

Georgia Institute of Technology; B,M,D
Atlanta, GA 30332
(404) 894-4154

Mercer University; B
Macon, GA 31207
(912) 744-2700

Middle Georgia College; A
Cochran, GA 31014

ILLINOIS

Illinois Institute of Technology; B
3300 South Federal Street
Chicago, IL 60616
(312) 567-3025

Parks College of St. Louis University; B
Cahokia, IL 62206
(618) 337-7500

Richland Community College; A
100 North Water Street
Decatur, IL 62523

University of Illinois at Urbana-Champaign; B,M,D
Urbana, IL 61801
(217) 333-1000

INDIANA

Purdue University; B,M,D,W
West Lafayette, IN 47907
(317) 494-1776

St. Joseph's College; B
Rensselaer, IN 47978
(219) 866-7111

Tri-State University; B
Angola, IN 46703
(219) 665-3141

University of Notre Dame; B,M,D
Notre Dame, IN 46556
(219) 239-5000

IOWA

Iowa State University of Science and Technology; B,M,D
Ames, IA 50011
(515) 294-5836

KANSAS

Coffeyville Community College; A
11th and Willow
Coffeyville, KS 67337
(316) 251-7700

University of Kansas; B,M,D
Lawrence, KS 66043
(913) 864-3911

Wichita State University; B,M
Wichita, KS 67208
(316) 689-3085

MARYLAND

Howard Community College; A
Little Patuxent Parkway
Columbia, MD 21044

United States Naval Academy; B
Annapolis, MD 21402
(301) 267-6100

University of Maryland Baltimore County; M,D
5401 Wilkens Avenue
Catonsville, MD 21228
(301) 455-2291

College Park; B,M,D
College Park, MD 20742
(301) 454-5550

MASSACHUSETTS

Boston University; B,M
Commonwealth Avenue
Boston, MA 02215
(617) 353-2000

Eastern Nazarene College; B
Wollaston Park
Quincy, MA 02170
(617) 773-6350

Massachusetts Institute of Technology; B,M,D,W
Cambridge, MA 02139
(617) 253-4791

Northeastern University; B
Boston, MA 02115
(617) 437-2200

Simmons College; B
300 The Fenway
Boston, MA 02115
(617) 738-2000

Stonehill College; B
North Easton, MA 02356
(617) 238-1081

Worcester Polytechnic Institute; B
Worcester, MA 01609
(508) 831-5000

MICHIGAN

University of Michigan; B,M,D
Ann Arbor, MI 48109
(313) 764-7433

Western Michigan University; B
Kalamazoo, MI 49008
(616) 383-1950

MINNESOTA

University of Minnesota: Twin Cities; B,M,D
Minneapolis, MN 55455
(612) 373-2144

MISSISSIPPI

Mississippi State University; B,M
Mississippi State, MS 39762
(601) 325-2224

MISSOURI

St. Louis University; B,M,D
221 North Grand Blvd.
St Louis, MO 63103
(314) 658-2500

University of Missouri: Columbia; B,M,D
Columbia, MO 65201
(314) 882-2121

Rolla; B,M,D
Rolla, MO 65401
(314) 341-4164

NEW JERSEY

Princeton University B,M,D
Princeton, NJ 08544
(609) 452-3060

Rutgers-The State University of New Jersey: New Brunswick Graduate Campus; M,D
New Brunswick, NJ 08903
(201) 932-3770

NEW YORK

City University of New York: City College; B
Covenant Avenue & West 138 Street
New York, NY 10031
(212) 690-6977

Columbia University: School of Engineering and Applied Science; M,D,W
Broadway & West 116 Street
New York, NY 10027
(212) 280-2521

Cornell University; M,D
Ithaca, NY 48103
(607) 256-1000

Dowling College; B
Oakdale, NY 11769
(516) 589-6100

New York Institute of Technology; B
Old Westbury, NY 11568

Polytechnic University:
Brooklyn; B,M,D
333 Jay Street
Brooklyn, NY 11201
(212) 643-2150

Long Island Campus; B
Rt. 110
Farmingdale, NY 11735

Rensselaer Polytechnic
Institute; B,M,D
Troy, NY 12181
(518) 270-6216

State University of New York
at Buffalo; B,M,D
1300 Elmwood Avenue
Buffalo, NY 14222
(716) 878-5511

Syracuse University; B,M,D
Syracuse, NY 13210
(315) 423-3611

United States Military
Academy; B
West Point, NY 10996
(914) 938-4041

University of Rochester; M,D
Rochester, NY 14627
(716) 275-3221

NORTH CAROLINA

North Carolina State
University; B
Raleigh, NC 27650
(919) 737-2434

St. Augustine's College; B
Raleigh, NC 27611
(919) 828-4451

OHIO

Air Force Institute of
Technology; M,D
Wright-Patterson
Air Force Base
Dayton, OH 45433

Case Western Reserve
University; B,M,D
University Circle
Cleveland, OH 44106
(216) 368-4450

Ohio State University:
Columbus Campus; B,M,D
Columbus, OH 43210
(614) 422-3980

University of Cincinnati;
B,M,D
Cincinnati, OH 45221
(513) 475-3427

University of Dayton; M,D
300 College Park Avenue
Dayton, OH 45469
(513) 229-4411

OKLAHOMA

Oklahoma State University; B
Stillwater, OK 74078
(405) 624-6384

Southeastern Oklahoma State
University; B
Durant, OK 74701
(405) 924-0121 ext. 381

University of Oklahoma;
B,M,D
Norman, OK 73019
(405) 325-2251

PENNSYLVANIA

Penn State University Park
Campus; B,M,D
University Park, PA 16802
(814) 865-4700

TENNESSEE

Middle Tennessee State
University; B
Murfreesboro, TN 37132
(615) 898-5555

Motlow State Community
College; A
Tullahoma, TN 37388

Tennessee State University; B
Nashville, TN 37203
(615) 320-3131

University of Tennessee:
Knoxville; B,M,D
Knoxville, TN 37996
(615) 974-2591

TEXAS

Rice University; M,D
6100 South Main
Houston, TX 77251
(713) 527-4036

Texas A&M University; B,M,D
College Station, TX 77843
(713) 845-1031

University of Texas:
Arlington; B,M,D
Arlington, TX 76019
(817) 273-3401

Austin; B,M,D
Austin, TX 78712
(512) 471-1711

VIRGINIA

Mountain Empire Community
College; A
Drawer 700
Big Stone Gap, VA 24219

University of Virginia; B,M,D
Box 3728
University Station
Charlottesville, VA 22903
(804) 924-7751

Virginia Polytechnic Institute
and State University; B,M,D
Blacksburg, VA 24061
(703) 961-6267

WASHINGTON

Evergreen State College; B
Olympia, WA 98505
(206) 866-6000

University of Washington;
B,M,D
1400 Northeast Campus Way
Seattle, WA 98195
(206) 543-9686

WEST VIRGINIA

West Virginia University;
B,M,D
Morgantown, WV 26506
(304) 293-0111

AERONAUTICAL TECHNOLOGY

ALABAMA

Community College
of the Air Force; A
Maxwell AFB, AL 36112

Patrick Henry State Junior
College; A
Monroeville, AL 36460
(205) 575-3156

Wallace State Community
College at Hanceville; A
Hanceville, Alabama 35077
(205) 352-6403

ARIZONA

Arizona State University; B,M
Tempe, AZ 85287
(602) 965-3255

CALIFORNIA

Bakersfield College; A
Bakersfield, CA 93305
(805) 395-4011

Chaffey College; A
Rancho Cucamonga, CA
91701
(714) 987-1737

College of the Redwoods; A
Eureka, CA 95501
(707) 443-8411

Cyprus College; A
Cypress, CA 90630
(714) 826-2220

Kings River Community
College; A
Reedley, CA 93654
(209) 638-3641

Merced College; A
Merced, CA 95348
(209) 384-6000

MiraCosta College; A
Oceanside, CA 92056
(619) 757-2121

Mount San Antonio College; A
Walnut, CA 91789
(714) 594-5611

Northrop University; A,B
Los Angeles, CA 90045
(213) 337-4413

Ohlone College; A
Fremont, CA 94539
(415) 659-6000

Orange Coast College; A
Costa Mesa, CA 92628
(714) 432-0202

Sacramento City College; A
Sacramento, CA 95822
(916) 449-7111

San Bernardino Valley
College; A
San Bernardino, CA 92410
(714) 888-6511

San Diego Miramar College; A
San Diego, CA 92126
(619) 693-6800

Santa Rosa Junior College; A
Santa Rosa, CA 95401
(707) 527-4011

Shasta College; A
Redding, CA 96099
(916) 225-4600

Solano Community
College; A
Suisun City, CA 94585
(707) 864-7000

Southwestern College; A
Chula Vista, CA 92010
(619) 421-6700

West Los Angeles College; A
Culver City, CA 90230
(213) 836-7110

COLORADO

Aims Community College; A
Greeley, CO 80632
(303) 330-8008

Colorado Northwestern
Community College; A
Rangely, CO 81648
(303) 774-1160

CONNECTICUT

Quinebaug Valley
Community College; A
Danielson, CT 06239
(203) 774-1160

Thames Valley State
Technical College; A
Norwich, CT 06360
(203) 886-0177

DELAWARE

Delaware Technical and
Community College:
Terry Campus; A
1832 North duPont Parkway
Dover, Delaware 19901
(302) 736-5321

DISTRICT OF COLUMBIA

University of the District of
Columbia; A
4200 Connecticut Ave., NW
Washington, D.C. 20008
(202) 282-7300

FLORIDA

Broward Community
College; A
Fort Lauderdale, FL 33301
(305) 761-7465

Embry-Riddle Aeronautical
University; A,B
Daytona Beach, FL 32014
(904) 239-6000

Gulf Coast Community
College; A
Panama City, FL 32401
(904) 769-1551

Manatee Community
College; A
Bradenton, FL 34207
(813) 755-1511

Miami-Dade Community
College; A
Miami, FL 33132
(305) 347-3221

GEORGIA

Clayton State College; A
PO Box 285
Morrow, GA 30260

HAWAII

University of Hawaii: Honolulu
Community College; A
Honolulu, HI 96822
(808) 948-8207

ILLINOIS

City Colleges of Chicago:
Richard J. Daley College; A
3939 West 79th Street
Chicago, IL 60652

Lewis University; A,B
Route 53
Romeoville, IL 60441
(815) 838-0500

Moody Bible Institute; B
820 North LaSalle Drive
Chicago, IL 60610

Parks College of St. Louis
University; A,B
Cahokia, IL 62206
(618) 337-7500

NASA

Rock Valley College; A
Rockford, IL 61101

Southern Illinois University at Carbondale; A
Carbondale, IL 62901
(618) 453-2121

INDIANA

Indiana State University; A,B
Terre Haute, IN 47809
(812) 232-6311

Purdue University; A,B
West Lafayette, IN 47907
(317) 494-1776

Vincennes University; A
1002 North First Street
Vincennes, IN 47591
(812) 882-3350

KANSAS

Central College; A
McPherson, KS 67460
(316) 241-0723

Hesston College; A
Box 3000
Hesston, KS 67062
(800) 835-2026

Johnson County Community College; A
12345 College Blvd.
Overland Park, KS 66210

LOUISIANA

Delgado Community College; A
615 City Park Avenue
New Orleans, LA 70119

Nicholls State University; A
Thibodaux, LA 70310
(504) 446-8111

MARYLAND

Frederick Community College; A
Frederick, MD 21701

Howard Community College; A
Little Patuxent Parkway
Columbia, MD 21044

MASSACHUSETTS

North Shore Community College; A
3 Essex Street
Beverly, MA 01915

Roxbury Community College; A
Roxbury, MA 02119

Wentworth Institute of Technology; A
550 Huntington Avenue
Boston, MA 02115
(617) 442-9010

MICHIGAN

Andrews University; A
Berrien Springs, MI 49104
(616) 471-7771

Charles Stewart Mott Community College; A
1401 East Court Street
Flint, MI 48503

Ferris State University; A
Big Rapids, MI 49307
(616) 796-9971

Jackson Community College; A
Jackson, MI 49201

Kirtland Community College; A
Roscommon, MI 48653

Lansing Community College; A
419 North Capitol
Lansing, MI 48914

Macomb Commmunity College; A
Mt. Clemens, MI 48044

Southwestern Michigan College; A
Cherry Grove Road
Dowagiac, MI 49047

Wayne County Community College; A
4612 Woodward Avenue
Detroit, MI 48201

Western Michigan University; B
Kalamazoo, MI 49008
(616) 383-1950

MISSISSIPPI

East Mississippi Junior College; A
Scooba, MS 39358
(601) 476-2111

Hinds Community College; A
Raymond, MS 39154
(601) 857-5261

MISSOURI

Calvary Bible College; A
Kansas City, MO 64147

Central Missouri State University; A,B
Warrensburg, MO 64093
(816) 429-4111

St. Louis University; A
221 North Grand Blvd.
St. Louis, MO 63103
(314) 658-2500

NEW HAMPSHIRE

Daniel Webster College; A
University Drive
Nashua, NH 03063
(603) 883-3556

NEW YORK

State University of New York College of Technology at Farmingdale; A
Farmingdale, NY 11735
(516) 420-2000

NORTH CAROLINA

Guilford Technical Community College; A
5800 Friendly Avenue
Guildford College, NC 27410
(919) 292-5511

Wayne Community College; A
PO Box 8002
Goldsboro, NC 27530

OHIO

Bowling Green State University; B
Bowling Green, OH 43403
(419) 372-2086

Cincinnati Technical College; A
570 East Leffels Lane
PO Box 570
Springfield, OH 45501

Cuyahoga Community College: Western Campus; A
11000 Pleasant Valley Road
Parma, OH 44130

Ohio University; A
Athens, OH 45701
(614) 594-5174

OREGON

Lane Community College; A
Eugene, OR 97405

PENNSYLVANIA

Community College of Allegheny County; A
Monroeville, PA 15146

SOUTH CAROLINA

Florence-Darlington Technical College; A
PO Box 8000
Florence, SC 29501

TENNESSEE

Motlow State Community College; A
Tullahoma, TN 37388

TEXAS

Central Texas College; A
US Highway 190 West
Killeen, TX 76541
(817) 526-1211

El Paso Community College; A
PO Box 20500
El Paso, TX 79998

Lee College; A
Baytown, TX 77520

LeTourneau College; A,B
Longview, TX 75607
(214) 753-0231

Mountain View College; A
Dallas, TX 75202

Tarrant County Junior College; A
1400 The Electric Service Building
Fort Worth, TX 76102

Texarkana College; A
Texarkana, TX 75501

Texas State Technical Institute: Waco; A
Waco, TX 76705
(817) 799-3611

UTAH

Dixie College; A
225 South 700 East St.
George, UT 84770

Utah State University
Logan, UT 84322
(801) 750-1000

VIRGINIA

Northern Virginia Community College; A
8333 Little River Turnpike
Annandale, VA 22003

Tidewater Community College; A
Portsmouth, VA 23703

WASHINGTON

Big Bend Community College; A
28th and Chanute
Moses Lake, WA 98837

Everett Community College; A
801 Wetmore Avenue
Everett, WA 98201

Green River Community College; A
Auburn, WA 98002

South Seattle Community College; A
6000 16th Avenue SW
Seattle, WA 98106

Spokane Community College; A
North 1810 Greene Street
Spokane, WA 99207

Yakima Valley Community College; A
PO Box 1647
Yakima, WA 98907
(509) 575-2612

ASTRONOMY

ALABAMA

Alabama Agricultural and Mechanical University; B
Normal, AL 35762
(205) 859-7011

ARIZONA

University of Arizona; B,M,D
Huntsville, AL 35899
(205) 895-6120

CALIFORNIA

California Institute of Technology; B,M,D,W
Pasadena, CA 91125
(818) 356-6811

Chabot College; A
Hayward, CA 94545
(415) 786-6600

El Camino College; A
Torrance, CA 90506
(213) 532-3670

Fullerton College; A
Fullerton, CA 92634
(714) 992-7000

Modesto Junior College; A
Modesto, CA 95350
(209) 575-6498

Napa Valley College; A
Napa, CA 94558
(707) 253-3095

Ohlone College; A
Fremont, CA 94539
(415) 659-6000

Pomona College; B
Claremont, CA 91711
(714) 621-8000

Saddleback College; A
28000 Marguerite Parkway
Mission Viejo, CA 92692
(714) 582-4500

San Bernardino Valley College; A
San Bernardino, CA 92410
(714) 888-6511

San Diego State University; B,M
San Diego, CA 92182
(619) 594-5200

San Francisco State University; B
San Francisco, CA 94132
(415) 338-1111

Santa Monica College; A
Santa Monica, CA 90405
(213) 450-5150

Scripps College; B
Claremont, CA 91711
(714) 621-8000

Southwestern College; A
Chula Vista, CA 92010
(619) 421-6700

University of California:
Berkeley; B,M,D
Berkeley, CA 94720
(415) 642-6000

Los Angeles; B,M,D
Los Angeles, CA 90024
(213) 825-4321

Santa Cruz; M,D
Santa Cruz, CA 95064
(408) 429-0111

University of Southern California; B
Los Angeles, CA 90089
(213) 743-2311

CONNECTICUT

Wesleyan University; B,M
Middletown, CT 06457
(203) 347-9411

Western Connecticut State University; B
Danbury, CT 06810
(203) 797-4347

Yale University; B,M,D
New Haven, CT 06520
(203) 432-4771

DISTRICT OF COLUMBIA

Howard University; B
2400 6th Street, NW
Washington, D.C. 20059
(202) 636-6100

FLORIDA

Daytona Beach Community College; A
Daytona Beach, FL 32015
(904) 255-8131

University of Florida; B,M,D
Gainesville, FL 32611
(904) 392-3261

GEORGIA

University of Georgia; B
Athens, GA 30602
(404) 453-5187

Valdosta State College; B
Valdosta, GA 31601
(912) 247-3233

HAWAII

University of Hawaii at Manoa; M,D
2530 Dole Street C-200
Honolulu, HI 96822
(808) 948-8111

ILLINOIS

Northwestern University; B,M,D
633 Clark Street
Evanston, IL 60201
(312) 492-7456

University of Chicago; B,M,D
Chicago, IL 60637
(312) 753-1234

University of Illinois at Urbana-Champaign; B,M,D
Urbana, IL 61801
(217) 333-1000

INDIANA

Earlham College; B
Richmond, IN 47374
(317) 962-6561

Indiana University Bloomington; B,M,D
Bloomington, IN 47405
(812) 335-0661

IOWA

Drake University; B
Des Moines, IA 50311
(515) 271-3182

University of Iowa; B,M
Iowa City, IA 52242
(319) 353-3976

KANSAS

Benedictine College; B
Atchison, KS 66002
(913) 367-5340

University of Kansas; B
Lawrence, KS 66043
(913) 864-3911

LOUISIANA

Louisiana State University and Agricultural and Mechanical College; B
Baton Rouge, LA 70803
(504) 388-1686

MARYLAND

Howard Community College; A
Little Patuxent Parkway
Columbia, MD 21044

Johns Hopkins University; B,D
Baltimore, MD 21218
(301) 338-8171

University of Maryland: College Park; B,M,D
College Park, MD 20742
(301) 454-5550

MASSACHUSETTS

Amherst College; B
Amherst, MA 01002
(413) 542-2328

Boston University; B,M,D
Commonwealth Avenue
Boston, MA 02215
(617) 353-2000

Hampshire College; B
Amherst, MA 01002
(413) 549-4600

Harvard and Radcliffe Colleges; B
Cambridge, MA 02138
(617) 495-1551

Massachusetts Institute of Technology; B,M,D,W
Cambridge, MA 02139
(617) 253-4791

Mount Holyoke College; B
South Hadley, MA 01075
(617) 538-2000

Smith College; B
Northampton, MA 01063
(413) 584-2700

Tufts University; B
Medford, MA 02155
(617) 628-0990

University of Massachusetts at Amherst; B,M,D
Amherst, MA 01003
(413) 545-0222

Wellesley College; B
Wellesley, MA 02181
(617) 235-0320

MICHIGAN

University of Michigan; B,M,D
Ann Arbor, MI 48109
(313) 764-7433

Wayne State University; B
5980 Cass Avenue
Detroit, MI 48202
(313) 577-3577

MINNESOTA

Mankato State University; B
Mankato, MN 56001
(800) 722-0544

University of Minnesota: Twin Cities; M
Minneapolis, MN 55455
(612) 373-2144

MONTANA

Montana State University; B
Bozeman, MT 59717
(406) 994-2452

NEBRASKA

University of Nebraska-Lincoln; B,M,D
Lincoln, NE 68508
(402) 472-3601

NEW MEXICO

New Mexico State University; M,D
Las Cruces, NM 88003
(505) 646-3121

NEW YORK

Colgate University; B
Hamilton, NY 13346
(315) 824-1000

Columbia University: Columbia College; B
Broadway & West 116 Street
New York, NY 10027
(212) 280-2521

Cornell University; M,D
Ithaca, NY 48103
(607) 256-1000

State University of New York at Stony Brook; B
Stony Brook, NY 11794
(516) 246-5126

University of Rochester; D,W
Rochester, NY 14627
(716) 275-3221

Vassar College; B
Poughkeepsie, NY 12601
(914) 452-7000

NORTH CAROLINA

University of North Carolina at Chapel Hill; B,M,D
Chapel Hill, NC 27514
(919) 966-3621

OHIO

Case Western Reserve University; B,M,D
University Circle
Cleveland, OH 44106
(216) 368-4450

Mount Union College; B
Alliance, OH 44601
(216) 821-5320

Ohio State University: Columbus Campus; B,M,D
Columbus, OH 43210
(614) 422-3980

Ohio Wesleyan University; B
Delaware, OH 43015
(614) 369-4431

Otterbein College; B
Westerville, OH 43081
(614) 890-3000

University of Akron; B
302 East Buchtel Avenue
Akron, OH 44325
(216) 375-7100

University of Toledo; D
Toledo, OH 43606
(419) 537-2696

Youngstown State University; B
Youngstown, OH 44555
(216) 742-3150

OKLAHOMA

University of Oklahoma; B
Norman, OK 73019
(405) 325-2251

PENNSYLVANIA

Bryn Mawr College; B
Bryn Mawr, PA 19010
(215) 645-5152

Haverford College; B
Haverford, PA 19041
(215) 896-1000

Lycoming College; B
Williamsport, PA 17701
(717) 326-1951

Penn State University Park Campus; B,M,D
University Park, PA 16802
(814) 865-4700

Swarthmore College; B
Swarthmore, PA 19081
(215) 447-7300

University of Pennsylvania; B,M,D
Philadelphia, PA 19104
(215) 243-7507

University of Pittsburgh; B,M,D
4200 Fifth Avenue
Pittsburgh, PA 15260
(412) 624-4141

Villanova University; B
Villanova, PA 19085
(215) 645-4000

RHODE ISLAND

Brown University; B
79 Waterman Street
Providence, RI 02912
(401) 863-2378

TENNESSEE

Vanderbilt University; B,M
Nashville, TN 37212
(615) 322-2561

TEXAS

Austin Community College; A
PO Box 2285
Austin, TX 78768

Rice University; M,D
6100 South Main
Houston, TX 77251
(713) 527-4036

San Antonio College; A
San Antonio, TX 78284

UNIVERSITY OF COLORADO AT BOULDER

Texas Christian University; B
2800 University Drive
Fort Worth, TX 76129
(817) 921-7490

University of Texas at Austin; B,M,D
Austin, TX 78712
(512) 471-1711

Western Texas College; A
Snyder, TX 79549
(915) 573-8511

VERMONT

Bennington College; B
Marlboro College; B
Marlboro, VT 05344
(802) 257-4333

VIRGINIA

University of Virginia; B,M,D
Box 3728 University Station
Charlottesville, VA 22903
(804) 924-7751

WASHINGTON

Lower Columbia College; A
Longview, WA 98632

University of Washington; B,M,D
1400 Northeast Campus Way
Seattle, WA 98195
(206) 543-9686

Western Washington University; B
Bellingham, WA 98225
(206) 676-3000

Whitman College; B
Walla Walla, WA 99362
(509) 527-5176

WISCONSIN

University of Wisconsin: Madison; M,D
140 Peterson Building
750 University Avenue
Madison, WI 54408

WYOMING

University of Wyoming; B
Laramie, WY 82070
(307) 766-5160

ASTROPHYSICS

ALABAMA

Auburn University; M,D
Auburn, AL 36849
(205) 826-4000

ALASKA

University of Alaska Fairbanks; M,D
Fairbanks, Alaska 99775
(907) 474-7112

CALIFORNIA

San Francisco State University; B
San Francisco, CA 94132
(415) 338-1111

University of California: Santa Cruz; M,D
Santa Cruz, CA 95064
(408) 429-0111

COLORADO

University of Colorado at Boulder; D
Boulder, CO 80309
(303) 492-0111

CONNECTICUT

Wesleyan University; B,M,D
Middletown, CT 06457
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GEORGIA

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University Plaza
Atlanta, Georgia 30303
(404) 658-2000

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622 Clark Street
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(312) 492-7456

University of Chicago; B,M,D
Chicago, IL 60637
(312) 753-1234

INDIANA

Indiana University Bloomington; D
Bloomington, IN 47405
(812) 335-0661

Purdue University; M
West Lafayette, IN 47907
(317) 494-1776

IOWA

Iowa State University of Science and Technology; M,D
Ames, Iowa 50011
(515) 294-5836

MASSACHUSETTS

Boston University; B
Commonwealth Avenue
Boston, Mass. 02215
(617) 353-2000

Massachusetts Institute of Technology; B,M,D,W
Cambridge, Mass. 02139
(617) 253-4791

Tufts University; M,D
Medford, Mass. 02155
(617) 628-0990

Williams College; B
Williamstown, Mass. 01267
(413) 597-2211

MICHIGAN

Michigan State University; B
East Lansing, Mich. 48824
(517) 355-8332

MINNESOTA

University of Minnesota: Twin Cities; B,D
Minneapolis, Minn. 55455
(612) 373-2144

MONTANA

Montana State University; B
Bozeman, Montana 59717
(406) 994-2452

NEW JERSEY

Princeton University; B,D
Princeton, NJ 08544
(609) 452-3060

NEW MEXICO

New Mexico Institute of Mining and Technology; B,M,D
Socorro, NM 87801
(505) 835-5424

University of New Mexico; B
Albuquerque, NM 87131
(505) 277-0111

NEW YORK

City of New York: Brooklyn College; B
Bedford Avenue & Avenue H
New York, NY 11210
(212) 780-5485

Colgate University; B
Hamilton, NY 13346
(315) 824-1000

Columbia University: Columbia College; B
Broadway & West 116 Street
New York, NY 10027
(212) 280-2521

Cornell University; M,D
Ithaca, NY 48103
(607) 256-1000

United States Military Academy; B
West Point, NY 10996
(914) 938-4041

OHIO

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302 East Buchtel Avenue
Akron, Ohio 44325
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OKLAHOMA

University of Oklahoma; B
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Brown University; B
79 Waterman Street
Providence, RI 02912
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VERMONT

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Bennington, VT 05201
(802) 442-5401

Marlboro College; B
Marlboro, VT 05344
(802) 257-4333

VIRGINIA

University of Virginia; B
Box 3728 University Station
Charlottesville, VA 22903
(804) 924-7751

WISCONSIN

University of Wisconsin: Madison; B
140 Peterson Building
750 University Avenue
Madison, WI 54408
(608) 262-3961

WYOMING

University of Wyoming; B
Laramie, WY 82070
(307) 766-5160

PLANETARY SCIENCE

ARIZONA

University of Arizona; M,D
Tuscon, AZ 85721
(602) 621-3237

CALIFORNIA

California Institute of Technology; B,D
Pasadena, CA 91125
(818) 356-6811

COLORADO

University of Colorado at Boulder; M,D
Boulder, CO 80309
(303) 492-0111

FLORIDA

Florida Institute of Technology; B,M
Melbourne, FL 32901
(407) 768-8000

MARYLAND

Johns Hopkins University; B,M,D
Baltimore, MD 21218
(301) 338-8171

MASSACHUSETTS

Massachusetts Institute of Technology; B,M,D
Cambridge, MA 02139
(617) 253-4791

MONTANA

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Bozeman, MT 59717
(406) 994-2452

TEXAS

Tyler Junior College; A
PO Box 9020
Tyler, TX 75711

VIRGINIA

University of Virginia; M
Box 3728 University Station
Charlottesville, VA 22903
(804) 924-7751

WASHINGTON

Eastern Washington University; B
Chaney, WA 99004
(509) 359-2397

The Job Market: A Guide to Space Careers


NASA

So you're ready to join the space program. You have the skills you need to get involved, or you're in the process of acquiring them. You get so excited picturing yourself as part of this grand adventure that sometimes you can't get to sleep at night.

Now what?

The late Bart Giamatti, former major league baseball commissioner, once said, "There are many ways to love baseball. There are many routes to the game." The same thing is true of the space program. Fewer than a thousand humans will make the trek into Earth orbit before century's end. About the same number will sit in launch and mission control rooms. But behind every one of them will be thousands of supporting players, ranging from secretaries to senior engineers.

Despite its often glorious goals and awesome achievements, space exploration is primarily a business. "The things you'd expect to see in any production industry are needed here," says Bill Leach, senior personnel manager for the space systems division of Boeing Aerospace & Electronics Company. "A broad range of disciplines is required."

Of course, industry isn't the only road that will lead you into space. NASA and the Department of Defense are world leaders in aerospace research and development (R&D); the Departments of Transportation, Commerce and Energy also have limited but significant roles.

WHERE THE BUCKS STOP

The United States spends about $28 billion a year on space development, research, exploration and marketing. Most of that amount is forked over by the federal government; the remainder is spent by industry on private space projects and communications satellites, and by consumers on space-related merchandise such as books, clothing, videos and museums.

About 40% of government space expenditures go to NASA for non-military R&D and space operations. Another 60% is channeled to the military for defense, and a small amount goes to other government space programs such as the weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA).

NASA spends half of its money on research at the agency's field centers around the country, while the other half is used for support contracts (Lockheed, for example, processes the space shuttle between flights) and major hardware procurement. The Defense Department dishes out the majority of its appropriations to thousands of defense contractors and supporting subcontractors. The moral of the story? The jobs are where the money is.

WHERE THE JOBS ARE

There are currently more than 200,000 jobs tied to NASA projects alone, and that doesn't count careers in private and military space programs. Here's where to look to find one for yourself:

THE "GIANTS" (50%): The companies whose names are synonymous with big-time space. General Dynamics, Hughes, Lockheed, McDonnell Douglas, Boeing, Martin Marietta, IBM and Rockwell are among the heavy hitters in the United States. COMSAT doesn't build *anything*—its financial punch comes from its worldwide network of communications satellites. Arianespace, which builds and markets the Ariane launch vehicle, is the major non-U.S. player.

"SMALL" INDUSTRY (40%): Mostly subcontractors and suppliers of aerospace equipment, they come in all sizes. TRW, Harris, LTV, Hercules, GE Astrospace, Ford Aerospace and Sundstrand are some of the best-known corporations. These companies work extensively on government contracts, but rarely are primary contractors by


HERB STOKES


WYLE LABORATORIES


HERB STOKES

The field is competitive, but large com


NASA

themselves on major aerospace projects like the shuttle or space station Freedom.

NASA (about 3%): Includes NASA Headquarters in Washington and the NASA centers and affiliates around the country.

MILITARY GOVERNMENT (less than 3%): Civilian and military personnel in the Air Force space and satellite commands and in the Department of Defense.

ENTREPRENEURS (less than 3%): These are companies primarily in the commercial space business. The best-known names are Orbital Sciences Corporation (OSC), Spacehab, AMROC and Space Services, Inc.

NON-MILITARY GOVERNMENT (less than 1%): Includes such programs as resource mapping by the Department of the Interior using remote imaging satellites and satellite weather studies by NOAA.

SPACE RELATED MERCHANDISING (less than 1%): Employers such as space museums, space magazines, and space novelty manufacturers.

YOUR FIRST SMALL STEP...

Getting your foot in the aerospace door may seem somewhat intimidating. The field is highly competitive; government and industry both try to attract top graduates and the "best and brightest" people with some experience.

If you're convinced that a space career is for you, there are things you can do to better your chances of being hired. Experience helps, but it isn't necessary. Up to two-thirds of all vacant professional positions are filled by people with little or no experience.

It's a good idea to do your homework on the aerospace field if you're short on direct experience. "Budget estimators need to know how the space industry works in order to make accurate projections," Carol Lawrence of General Dynamics says, "and materials inspectors need to know what materials are appropriate for space."

Even if you've just started college, run, don't walk, to the placement office on campus. Many aerospace companies have co-operative education programs that give you a chance to gain some experience early, and co-op students often become employees upon graduation.

Al Bormann, corporate director of college relations for Rockwell International, suggests you stop by the placement office early even if you *aren't* interested in co-op programs. "Students must understand early on what it is the companies are seeking," he says. "They should beat a path to the career planning center to find out. The corporations view these as their major connections on campus."

You'll probably be surprised, says Bormann, to find that you don't need an aerospace engineering degree *per se* to have a space career. "A large portion of our employees aren't aerospace engineers," notes Bormann. "We have a very systems-oriented structure, so many disciplines come into play."

Rockwell is typical of the space industry "giants." The company hires more electrical engineers, mechanical engineers, and computer specialists than aerospace engineers. Bormann says that materials scientists, civil engineers and chemical engineers also are in demand.

Nancy Kimerly, manager of professional staffing at General Dynamics Space Systems Division, reports that her division follows a similar hiring pattern. She adds that the company also seeks safety engineers, manufacturing engineers, test and evaluation engineers and quality control engineers.

WHAT IF YOU'RE NOT AN ENGINEER OR SCIENTIST?

If the preceding litany of "engineers" and "scientists" has you buffaloed, don't be. You don't need a technical degree to work in the aerospace field; some positions, in fact, don't require a degree at all.

Bill Leach, senior personnel manager for the space systems division of Boeing Aerospace & Electronics Co., says there's a rule of thumb for the aerospace industry: engineers and technicians are only one-third of the work force. The remainder are non-technical support personnel.

For companies specializing in design, the percentage of technical employees is slightly higher; for production companies that turn out pieces of hardware, the percentage of technical types may be as low as 10-15 percent.

The non-engineering staff of a "typical" space company is composed of 10-20 percent professional employees such as managers, salespeople and contract administrators. Technical, non-professional employees such as mechanics, electricians and drafters

NASA

panies hire hundreds, even thousands, of people each year.

account for another 5-10 percent. And usually, at least *half* of an aerospace employer's work force are non- technical, non-professional staffers: personnel specialists, engineering records employees, secretaries and assembly workers.

CHOOSING YOUR TARGET

Most companies are hiring, even those that don't advertise vacant positions. As primary contractor on the space station crew habitat and lab module, Boeing Aerospace and Electronics in Huntsville, Alabama currently employs 900 people, and that number is growing steadily. Rockwell International has more than 150 people working on the space shuttle and about 120 working on space station Freedom. General Dynamics Space Systems Division recently advertised openings in more than fifty career fields.

If a firm is doing well, it hires steadily to replace departing employees. This "turnover" hiring often is done from resumes on file, so employment officers usually are willing to look at your resume.

You won't be alone, of course. Nancy Kimerly of General Dynamics reports that her office reviews 500-700 resumes each *week*. At Rockwell, that number approaches 1000 during the spring and fall hiring seasons. There's no denying that space industry hiring is competitive, but it's a pretty large pond: large aerospace companies hire hundreds, even thousands, of people each year.

For best results, Rockwell's Al Bormann suggests resumes be sent in September for the fall hiring cycle, and in February for the spring cycle. He adds that, despite the efforts of his staff, resumes and cover letters frequently become separated. So be sure all pertinent information (such as the position you are seeking, the date you will be available for employment, home and work phone numbers and home address) is on your resume.

Bormann also advises that college grades need only be good, not necessarily outstanding—communication and leadership skills are equally important.

ROUND PEG, SQUARE HOLE?

The tremendous size and sophistication of space projects makes it only natural that large companies get most of the contracts and, subsequently, do most of the hiring. But perhaps you don't see yourself as a corporate tiger with a huge, "impersonal" company.

For every "giant" there are dozens of small subcontractors providing specialized products and services. For example, Space Industries, near Houston, Texas, is designing the space station's free-flying platform using a mere 35 people. At ARINC Research Corp in Colorado Springs, Colorado, it takes just a few hundred employees to design satellite tracking stations and ground control systems. In addition, even the big boys have small divisions scattered around the country.

The idea of living in California or Florida doesn't appeal to you? Then try Utah, Missouri, Ohio, Delaware—or just about any other state. To find aerospace companies in a particular area, contact the state's aeronautics division (usually in the department of transportation) or the local chapter of any space society.

CHANGING CAREERS

Even if you've been counting beans or making widgets for a number of years, you still may be able to fashion a career in space. Many business and manufacturing skills are directly transferable; if you're not too old to change jobs *within* a particular industry, you're not too old to join the aerospace field.

A space career isn't a panacea, however. If you're genuinely discontent with the type of work you do, doing something comparable in the space arena probably won't help matters. A young engineer recently quit his job as a thermal analyst for Lockheed, even though he was working for NASA on several hot programs.

"I worked on a bunch of different projects," he says, "but I did the same exact thing on each one. They'd give me some numbers and I'd crunch them. Day after day. I just got sick of it."

THE BOTTOM LINE

You know a career in aerospace is for you, so start finding *your* route to the stars *now*.

- If you're a high school or college student, tailor your curriculum to make yourself appealing to a prospective government or private employer. Play to your strengths; if math and science leave you hopelessly lost, there are numerous business majors that are just as valuable to aerospace corporations.
- Read everything you can get your hands on about space. Don't focus exclusively on present and future programs, or just on NASA.
- Get some *firsthand* knowledge as well. Try to find someone who's already working in the space career you'd like to follow, and find out what it's *really* like. They may be able to "network" you into a position if you have the right background.
- You have about ten seconds to catch a prospective employer's attention with a cover letter and resume before you're put into the "INTERVIEW" or "REJECT" pile. If you're turned down, try to discover the reason. Is it your background, or merely your presentation?
- Remember that a space career is not just an adventure, it's a job. Make sure it's what you want to do for the next forty-plus years, forty-plus hours a week.

AEROSPACE COMPANIES

Many corporations do not have a designated "mail stop" or department number for their personnel or human resources division. Where no specific employment address is indicated, the company suggests that you simply send your resume to the attention of "Personnel."

Aerojet General
P.O. Box 13222
Sacramento, CA 95813
Rocket motors, advanced propulsion concepts

Allied-Signal Aerospace Company
(Includes AiResearch, Garrett Fluid Systems and Bendix Field Engineering)
2525 W. 190th Street
Torrance, CA 90509
Tracking, communications, space shuttle operations

American Rocket Company (AMROC)
847 Flynn Road
Camarillo, CA 93010
Private launch vehicle and payload services

Arianespace
Attn: Jacque Werschine
Boulevard de L'Europe
BP 177 Evry
9100 FRANCE
Builds and markets Ariane booster; facilities in France and Kourou, French Guiana

ARINC Research Corporation
Attn: Professional Staffing
Dept. 393
4410 E. Fountain Blvd. #100
Colorado Springs, CO 80916
Systems engineering, satellite tracking and control

Atlantic Research Corporation
1375 Piccard Drive
Rockville, MD 20850
Small rocket motors, defense systems, NASA support contractor

Ball Aerospace Systems Group
Human Resources
Dept. 53775
P.O. Box 1062
Boulder, CO 80306
Major subcontractor to NASA, DoD

Battelle Columbus Laboratories
505 King Ave.
Columbus, OH 43201
Research and development, operates advanced materials center for NASA

Boeing Employment Center, MS 31-13
P.O. Box 3707
Seattle, WA 98124
Aerospace & Electronics Company is space station contractor, military space supplier

CAE-Link Corporation
2224 Bay Area Blvd.
Houston, TX 77058
Aerospace flight simulators

CEC Instruments
955 Overland Court
San Dimas, CA 91773
Pressure and vibration sensors

Communications Satellite Corporation (COMSAT)
850 L'Enfant Plaza, S.W.
Washington, DC 20024
Manages satellite telecommunications network

Computer Sciences Corporation
2100 East Grand Ave.
El Segundo, CA 90245
Computer systems technology, software development for NASA and other government agencies

CONATEC, Inc.
P.O. Box 171
Glendale, MD 20769
Private suborbital launch vehicle services

Contel ASC
1801 Research Blvd.
Rockville, MD 20850
Operates Tracking and Data Relay Satellite System (TDRSS) for NASA

EOSAT
4300 Forbes Blvd.
Lanham, MD 20706
Markets LANDSAT data

E-Prime Aerospace Corporation
P.O. Box 792
Titusville, FL 32781
Private launch vehicle and payload services

E-Systems, Inc
Attn: Staffing
P.O. Box 1056
Greenville, TX 75401
Electronics for FLTSATCOM, MILSTAR, NAVSTAR

External Tanks Corporation (ETCO)
1877 Broadway
Boulder, CO 80302
Proposes use of shuttle external tanks as orbiting research platforms

Fairchild Space Company
20301 Century Blvd.
Germantown, MD 20874
Defense, NASA subcontractor

Ford Aerospace
Space Systems Division
MS D-03
3825 Fabian Way
Palo Alto, CA 94303
Space station power systems, spacecraft electro-optical systems

GE Astrospace
Employee Relations
Dept NTB
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If being an astronaut is still the only job for you, here's who to write: Astronaut Selection Office, Mail Code AHX, Johnson Space Center, Houston 77058. NASA takes applications for pilot astronauts and mission specialists on a continuing basis, with selections made about every two years.

You'll need *at least* a bachelor's degree in engineering, biological science, physical science or math. Mission specialists must also have three years of related professional experience, while pilot candidates need to have logged at least 1,000 hours in command of jet aircraft.

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GREAT GIFTS FOR THE SPACE-ENTHUSIAST!

Members of Skylab's 84-day club talk about living and working onboard a space station.

MARATHON MEN

In 1995 the United States, along with its partners in Europe, Japan and Canada, will begin building a permanent space station 200 miles above the Earth. Once completed in 1999, the Freedom base will be many things: research laboratory, technology center, observation post and home for eight people at a time. It also is the centerpiece of NASA's space program for the rest of this century.

In coming issues we will take an in-depth look at this mega-project, covering the technology and the politics, the assembly of the station, day-to-day life onboard, and Freedom's evolution into a base for reaching the Moon and Mars.

We begin with a nod to the past: America's first space station, Skylab. Nine astronauts–three crews of three–lived on this temporary orbital outpost from May 1973 to February 1974, conducting investigations in life sciences, solar physics, Earth observation, astronomy and materials processing. As much as anything, Skylab was an experiment in living. The last mission, Skylab 4, lasted 84 days, which remains the longest U.S. spaceflight.

A typical tour on Freedom will eventually last 180 days, although medical conservatism at first calls for stays of only 90 days. Space station astronauts will work around the clock in shifts, with the eight-member crew divided into two teams of four. Every 90 days, a space shuttle will arrive with fresh supplies and four new crew members.

As the only American astronauts who've lived three months at a time in space, the Skylab 4 crew of Gerald Carr, Edward Gibson and William Pogue offer valuable experience to Freedom's planners. All three are currently consultants on the project. Gibson works for Booz, Allen and Hamilton in Reston, Virginia, on space station operations planning. Carr and Pogue work for a small consulting firm, CAMUS, which provides the experience of former astronauts and spaceflight engineers to such companies as Boeing and Aeritalia.

We talked with the three Skylab 4 astronauts recently about space station life in the 1970s and in the 1990s.

–Tony Reichhardt

GERALD CARR

Final Frontier: One of the biggest physical differences between Freedom and Skylab is that Skylab had lots of open volume. Freedom will have more overall volume, but it's divided into smaller rooms. Do you see advantages to those larger Skylab modules?

Carr: All the volume we had on Skylab was just there because of the availability of the S4B [Saturn rocket stage] as a pressure vessel. But it really wasn't absolutely necessary. I'm pretty much convinced that the 15-foot diameter modules that are shuttle-compatible really make the most sense, because when you look out over the long haul, that is going to have to be your standard volume.

There are even some advantages to having [the modules] smaller, in terms of body restraint. If you can touch a toe to the floor and reach up and touch the ceiling, then you can instantly stop yourself or retain yourself in a position. But you get out in the middle of [Skylab's] great big volume, and it can be a very frustrating experience trying to get back to a hand-hold. You end up having to drift for ten or fifteen minutes to get there, or have somebody come and intercept you and push you up against something that you can grab hold of and continue your work.

So I don't see any great advantage to having a whole lot of volume. It's going to be interesting to see if the design we have for the space station gives people a closed-in feeling and makes them feel more restrained. But the way you get around that is putting in windows, and we've got some nice windows in [Freedom's] wardroom area and in the exercise area. I think this will help people from feeling like they're shut in.

Final Frontier: When the budget gets tight, are windows among the first things people want to take out?

Carr: Well, I wouldn't be surprised. The engineers realize the need for windows, but they also make it clear that you are paying for them in terms of structural integrity and the extra money and weight you have to put into a vehicle to make those windows safe. The crew is very much interested in having a small window in each stateroom, but I think they're going to have a real battle getting them–I think economics will probably overpower that one. But I certainly sympathize with the desire to have them.

Final Frontier: Let's talk about the sleeping quarters. It seems a unanimous opinion that people need a place for privacy. But the individual berths are only the size of a phone booth. Is that enough room?

Carr: Considering what volume is available, I don't think you can ask for any more than that. But the important thing is that it is your place, and you can make it your own. The crew quarters we're looking at on space station are slightly larger than the ones we had on Skylab, which were pretty nice. We had enough room in there to dress, to sleep comfortably, to write or listen to music, that sort of thing. We're trying to add more amenities to the crew quarters for space station in order to make it an even more pleasant place to be, with maybe a little color to match your own preferences, and equipment available for you to do creative things like write.

Final Frontier: Do you think it would have been acceptable to live on Skylab for, say, six months?

Carr: I think that would have been a

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ED GIBSON

Final Frontier: Do you have a feeling for what is an optimum amount of time to live in orbit?

Gibson: The body does a good job of adapting to the new environment, and we are learning a great deal about the specifics. I feel confident that you could stay up [in space] for numbers of years. It's more a psychological question from the standpoint of being separated from friends, family and having a productive job which you can approach creatively, same as you do down here. You need something that is challenging to you. If you have strictly mundane tasks, you can do them for just so many weeks or months at a time, and then your performance drops.

It needs to be continuously emphasized that the long-term nature of these missions allows you to take advantage of the human intellect. Short-term missions you almost have to plan by cookbook and by rote. But now you have a chance to put people up there, learn from what they are doing and improve the total quality of the operation, so it's as if you were working in a lab down here.

On Skylab we had the Apollo telescope, for example, where we studied the Sun. We had a great deal of flexibility in how we operated it, and the quality of the data correspondingly improved as the mission went on. We had other experiments which were done by rote, and I suspect that the quality of the data was the same on the last day as it was on the first day. The space station has got to, where it makes sense, use the onboard person as a true co-investigator right along with the people on the ground.

Final Frontier: Is that an argument for getting laboratory scientists up to the space station whenever possible, instead of career astronauts?

Gibson: To a degree, I think it makes sense. If you've got a couple of major payloads where a particular kind of expertise is beneficial, then it makes sense to go outside [NASA] and select people, get them in the training cycle early so they're not only expert in their equipment, but also understand how to operate the flight safely and are a positive addition to the crew. Yes, you should do that.

But if you have 20 experiments, you can't have 20 different principle investigators up there. So you really have to ask which ones are of major scientific consequence. A number of them really will require judgment on the part of the user, much more than people imagine.

Final Frontier: On Skylab, of course, you all were career astronauts. On

Pages 42-43: Gibson, Carr and Pogue with their orbiting hotel. In Skylab's spacious modules (opposite), finding your way to a hand-hold could be frustrating. Freedom will have more volume, but smaller rooms.

some shuttle missions you have payload specialists who aren't NASA employees. How will the jobs be defined on the space station?

Gibson: We have different names for them, but in general you still have the career astronaut, the flyer, who worries about getting the shuttle up and back. And then you have people onboard the station, including a commander, who worries about how to run the total day-to-day operation of the station. Then you have the people who are more interested in the science.

Final Frontier: Will you be able to take scientists right out of the university and fly them, or will they have to be involved in years of training beforehand?

Gibson: Well, you would like not to have people spend their full time over many years in training. They'll have to become experts in their particular area, for sure. Then there has to be an integration into the NASA system so that they can operate as a real team, partly for safety's sake, but also because you need a harmonious interaction of the crew. If it's not harmonious you really degrade the total operation in space. And it's been found that the way to solve that is to have people work things over on the ground and get all of their idiosyncrasies and differences of opinion ironed out before they fly. Time is far too expensive on the space station to iron things out in flight.

I've not been directly involved in Spacelab, so all the comments I hear are second-hand. But they ran into problems when they did not take the time on the ground to operate as a total crew long enough to find out where these idiosyncrasies are in people. And each person has got them.

Final Frontier: There's going to be some "tele-science" on Freedom where investigators on the ground are directly involved in running the onboard experiments. You had virtually none of that on Skylab.

Gibson: Very little. We sent some data down to Earth via TV and got some back up. We had tele-science in the sense that some of the data from the Apollo Telescope Mount were sent down daily with an electromagnetic scanner, but a very, very small amount of it.

I think tele-science is a good idea, but it ought to be used properly. It

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BILL POGUE

Final Frontier: The current thinking is that all eight crew members on Freedom will have the same day off each week. Do you think people will retreat to their corners on those days, or hang out together in the wardroom?

Pogue: It depends on how you feel. We did everything on Skylab. Sometimes we would read, sometimes we would go look out the window, sometimes people would go in their crew quarters. My general recollection is that we did not become reclusive on our days off. We used it as a time to recharge the batteries, so to speak, and escape from the heavy time pressure.

My personal feeling is that the cupola is going to be a very popular place.

Final Frontier: Because of the view?

Pogue: Yes, just looking out the windows.

Final Frontier: Did you find that you looked out the window less the longer you were up?

Pogue: No, I did not. I've heard some crew members say they got tired of looking out the window. I never did myself.

Final Frontier: Several of the long-term Soviet cosmonauts talk about the importance of maintaining a good relationship with ground crews during a mission. Any advice for making sure that goes smoothly?

Pogue: The main thing is to have a communication link between the flight crew and the ground teams, which isn't open to anyone who would like to listen in. I'm not saying it should be encrypted, although I wouldn't oppose it. But you need to be able to call them up and say, "Hey, I just screwed up something here." Or the ground crew can call you up and say "Stop everything–we gave you a wrong procedure." If you do that over an open loop, it sounds like you've got a bunch of ham-fisted operators working either on the ground or in flight, while the fact of the matter is that human error is just a fact of life, and people make mistakes.

Final Frontier: Freedom will obviously rely much more heavily on automated systems and robotics than you did on Skylab. Are people thinking about how that new environment is going to affect the crews?

Pogue: I think the thing that will make robotics acceptable to the crew members is that they are beneficial–in other words, that they function in the way they were designed to function, and that they provide a definite benefit to the crew instead of being a liability. If you have an automated system that ends up costing you more time than if you did the job manually, then that system is not going to have credibility in the eyes of the crew members, and they're going to resent it. It's going to rob them of time instead of saving them time. If they have a system that saves them time, and particularly, relieves them of boring and tedious work, then they'll hail it with open arms.

One of the big problems I see in robotics, artificial intelligence, expert systems and all that, is that the people who design these things design them in a corner, divorced from the operational context.

I would like to see these systems, first off, be designed to be able to function in degraded mode–that is, not a case where it all works or nothing works. If the system has a partial failure, you should still be able to work it in a supervisory or participating role.

The big problem I see looming with the use of automation and robotics is this failure to properly consider the human operator's role. You have to make sure you have good operator input early in the conceptual phases of the design.

Final Frontier: Is there any area of "human factors" planning for Freedom that you think needs more attention, that isn't being addressed?

Pogue: One of the things that bothers me is the extensive medical testing that's going to be required to qualify crew members for longer flights. I'm a bit concerned that this is going to become more elaborate than is actually required. I'm not badmouthing the effort, because I wouldn't know what else to suggest. But I'm afraid it's like anything else we do in this

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SMALL WONDERS

It all started with a silvery sphere only 20 inches in diameter. Ever since Sputnik 1, satellites have been getting bigger, more complex and more expensive, until only the space shuttle can carry them and only the government can afford them. Take Milstar, for instance. One of the more capable spacecraft ever devised by the military, this massive communications satellite system has already cost the federal treasury $5 billion, and the first one won't fly until 1991. Each copy will cost the Pentagon $1 billion to build and launch.

But in October 1985 a satellite called GLOMR (Global Low Rate Message Relay), slightly bigger than a basketball and costing less than a million dollars, came floating out of the space shuttle Challenger's cargo bay and into orbit. GLOMR was the forerunner of a new breed of satellite whose attributes—small, light, and best of all, inexpensive—are meant to put space within reach for unprecedented numbers of people, from battlefield commanders to farmers to university researchers. LightSats, as they are called, promise a space revolution.

To imagine the potential impact of LightSats, consider how personal computers have changed our lives. Whereas earlier machines filled large rooms and carried huge price tags, the microcomputer ended all that and created a social as well as technological revolution. Their impact could be similar to what will happen if LightSats, the PC's of the space age, make space affordable.

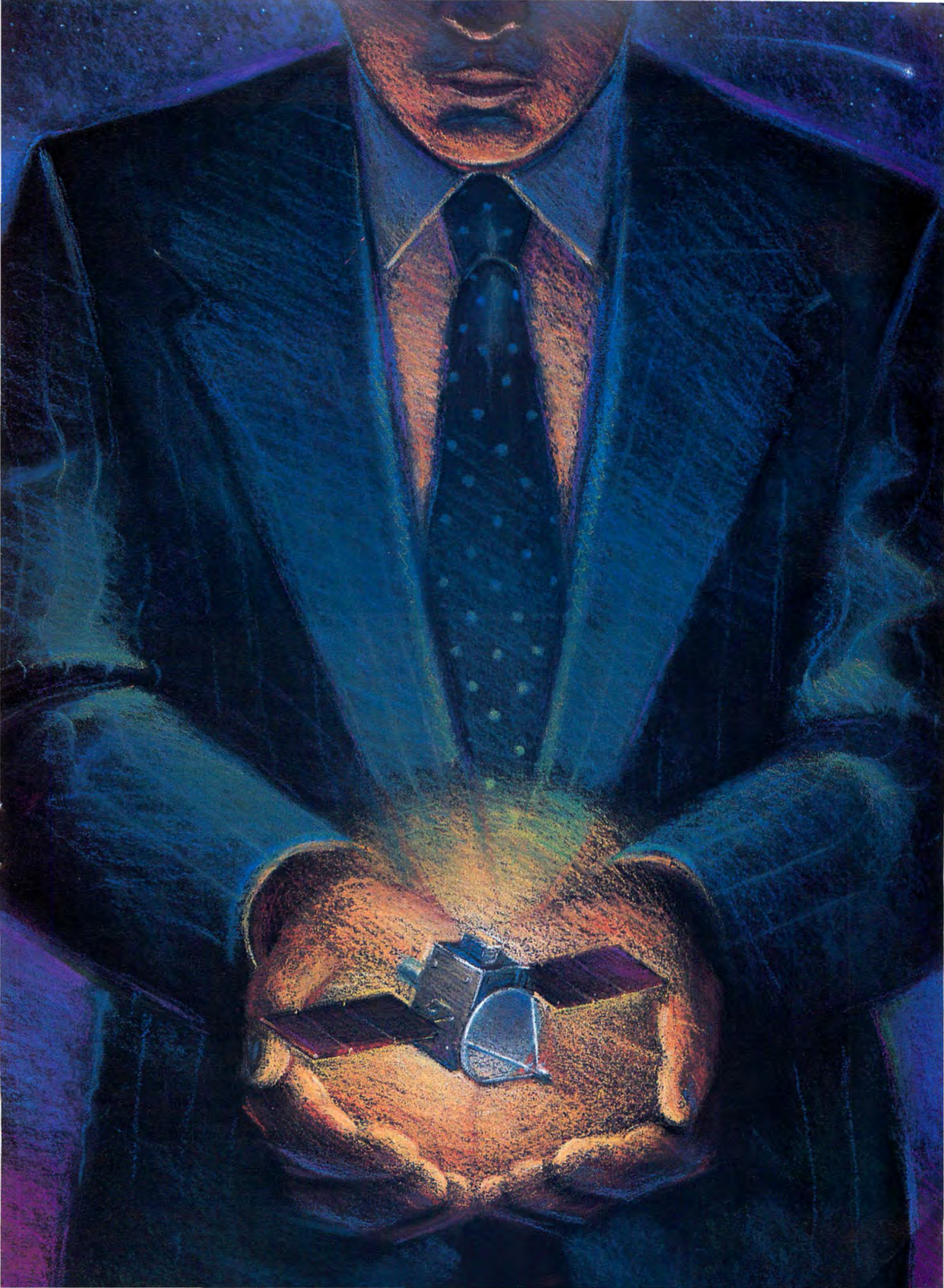
Imagine a company like Rand McNally being able to constantly update its road maps as routes go under construction or close down because of natural disasters. The Rand McNally RoadBird might relay images of routes throughout the world, even transmitting them directly to a display on your car's dashboard.

Farmers equipped with a small satellite dish and personal computer could download not just weather but soil condition data from an orbiting Iowa-Sat. And technology derived from LightSats may make it possible for widespread video phones to become reality, so that the next time grandma calls the grandkids, they'd be able to see each other.

Can't afford a billion-dollar satellite? Take heart—LightSats are coming. By Melinda Gipson

While these applications are farther in the future, an astronomy satellite called Alexis will soar into space in April 1991 to survey the universe at low-energy x-ray wavelengths. Los Alamos National Laboratories is building the satellite's x-ray telescopes and sensors, and Astronautics, an 11-member firm in Reston, Virginia, is building the "bus" that

LEE CHRISTIANSEN



ORBITAL SCIENCES CORPORATION

Pegasus, leader of the pack among potential LightSat boosters, was scheduled for its first launch from a B-52 bomber in late 1989.

provides the satellite's power, controls its orientation, communicates with ground stations and manages on-board computer memory. The entire package weighs only 225 pounds.

Astronautics is just one of a number of small companies that have sprung up to market LightSats. In an arena dominated by aerospace giants, smaller firms may have some advantages. Rick Fleeter, president of Astronautics, says that because his company is small, it can respond to changing customer needs more quickly than larger aerospace companies. Nevertheless, small firms will have to share the LightSat market with more established companies like Ball Aerospace of Boulder, Colorado.

Communications satellites typically cost tens of millions of dollars and weigh upwards of 2000 pounds. For $5 or $6 million, Ball will put a small satellite offering anywhere from one to ten separate communications channels and weighing less than 1000 pounds into orbit. For only three or four times that cost, they will provide any small, developing country with a satellite phone system that can reach even the most remote area. Jim Stuart, Ball Space Systems Division's chief scientist, notes: "What they want is not satellites, but phones." One interested potential customer is Thailand.

What has made it possible for pint-size satellites to step in for their huge, costly predecessors? According to Astronautics senior engineer Bob Dill, the most important advances have been in miniaturization of electronics. "Just as computers have gotten a lot smaller, you can put a lot more stuff into a very small box for a satellite now than you could, say, 10 or 20 years ago. We can fly something in a 200-pound-class satellite that you would have had a hard time fitting in a satellite weighing 2000 pounds or more 20 years ago."

Dill adds that LightSat manufacturers find many off-the-shelf components made for large satellites too big and much too expensive. For that reason, Astronautics has turned to making some components themselves, such as sun sensors used in guidance systems. "And if anybody wants some," he says, "we'd be happy to sell them."

Another big factor has been the development of relatively small, inexpensive launchers. As Jim Stuart points out, "It's not enough to promise an inexpensive satellite; you've got to get it up there." But now there is a fleet of real rockets–some on the drawing board and others already on the pad–ready to launch a LightSat regatta.

Orbital Sciences of Fairfax, Virginia, is marketing an innovative winged booster called Pegasus that is carried aloft under the wing of a B-52, then released to deliver a collection of satellites into orbit. They also offer a land-launched rocket called Taurus, which may sell commercially for about $16 million. The company's other rockets form a fleet that can carry payloads ranging from 400 to 1000 pounds.

Aside from newcomers like Pegasus and Taurus, customers have a stable of proven workhorses to choose from. The LTV Corporation, which has built and launched Scout rockets for NASA for decades, now holds the rights from the space agency to commercialize the venerable booster. Atlas rockets from General Dynamics, American Rocket's Industrial Launch Vehicle and Lockheed's rehabilitated Poseidon launcher are also in the running.

International competition in the smaller class of satellite launchers also is growing. For example, the French launch company Arianespace has offered cheap rides into orbit for up to six microsatellites (weighing as much as 90 pounds each) on a single flight. One multiple launch would cost less than $1 million, but the opportunity would only be offered once or twice a year. Mindful of its American competition, Ariane also has offered to launch

DATA BASE

1990 Calendar of Galactic Events

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French SPOT remote sensing satellite orbited by European Ariane rocket.

February
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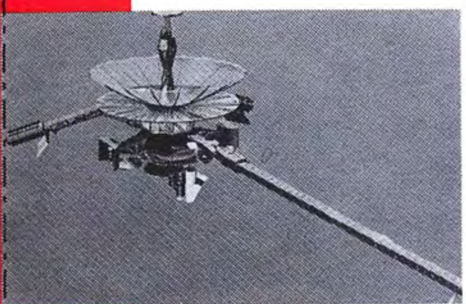
Space shuttle mission STS-36. Atlantis and a crew of five deliver a secret Defense Department payload to orbit.



February 9
Galileo spacecraft flies past Venus, the first planetary encounter on its six-year trip to Jupiter.

March 26
Space shuttle mission STS-31: Hubble Space Telescope launched from Discovery to begin operations as a revolutionary new astronomical observatory in Earth orbit.

April 26
ASTRO-1 space shuttle mission STS-35: Seven astronauts spend ten days conducting astronomical observations onboard Columbia.

June 4
Space shuttle mission STS-37: The second of NASA's "Great Observatories," the Gamma Ray Observatory, is launched from Atlantis.

July 9
STS-38 space shuttle mission: Five astronauts on-board Discovery fly a classified flight for the military.

August 10
Magellan spacecraft arrives in orbit around Venus to begin eight-months of mapping the planet's surface.

August 16
STS-40 space shuttle mission: Seven astronauts spend ten days conducting life science experiments inside Spacelab.

October
Ariane rocket orbits European Earth Resource Satellite (ERS-1) to conduct observations of Earth.

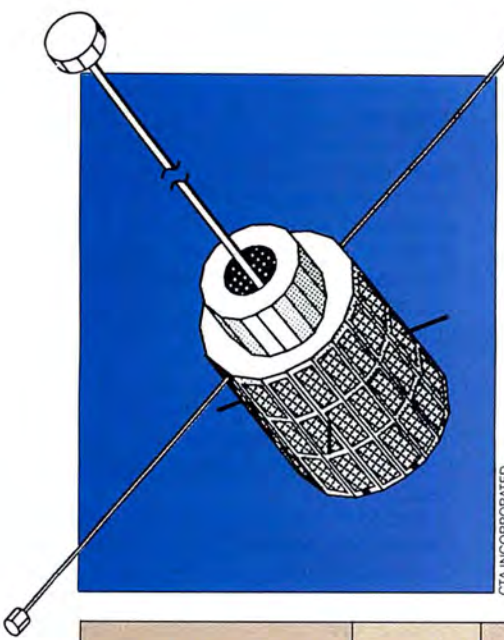
October 5
STS-41 space shuttle mission: European/U.S. Ulysses probe is launched from Atlantis into an orbit around the Sun's poles.

November 1
STS-39 space shuttle mission: Seven astronauts conduct SDI infrared experiments and other observations from onboard Discovery.

December 6
STS-42 space shuttle mission: International Microgravity Lab mission has seven astronauts working on experiments inside Columbia/Spacelab module for ten days.

December 8
Galileo spacecraft, bound for Jupiter, passes Earth at close range to receive a gravity boost.

All launch dates are subject to change.



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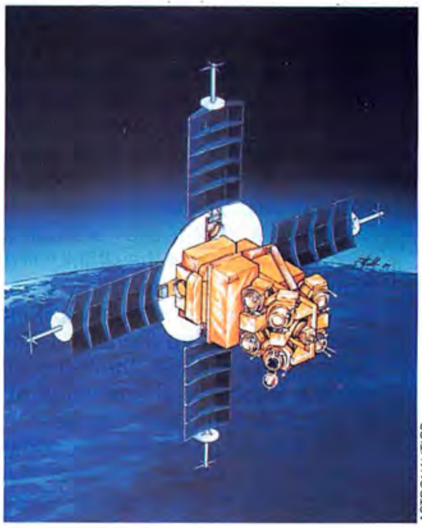
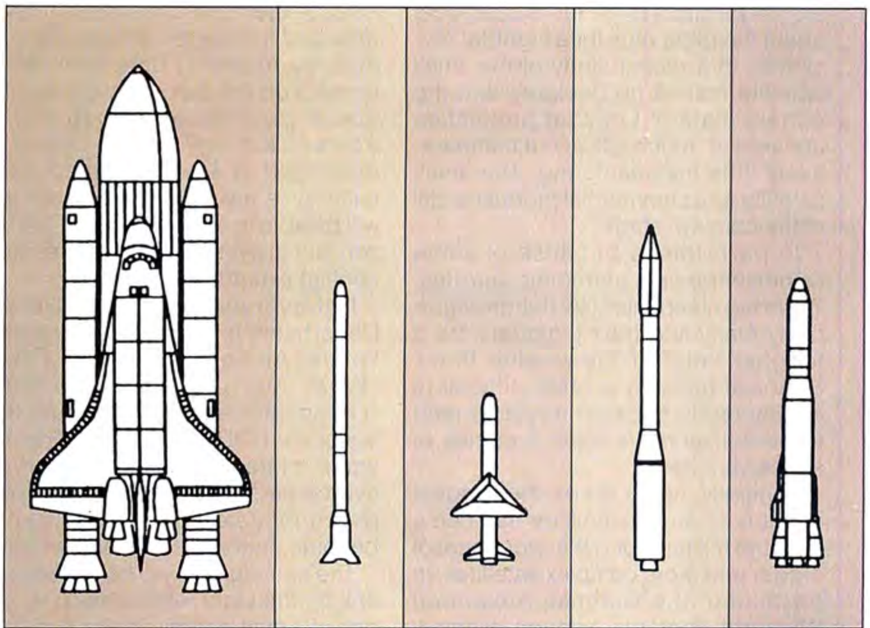


ASTRONAUTICS

BALL AEROSPACE

LightSats for all seasons: A battlefield reconnaissance satellite called TIDES (above left) would weigh less than 450 pounds and have no moving parts; ALEXIS (center) will survey the x-ray universe; Ball Aerospace's BGS-400 communications satellite would be lofted into orbit aboard a Taurus booster.



	SCOUT	PEGASUS	TAURUS	ATLAS-E
COMPANY	LTV CORP.	ORBITAL SCIENCES CORP.	ORBITAL SCIENCES CORP.	GENERAL DYNAMICS
POUNDS TO LOW-EARTH POLAR ORBIT	460	840	3,000	3,800

SOURCE: ORBITAL SCIENCES CORPORATION

Contenders for the LightSat launch market, with the Space Shuttle shown for scale.

any satellite weighing up to 1100 pounds for "on the order of $10 million."

These developments are generating a great deal of excitement in a number of fields, including scientific research. Scientists wishing to place a small payload in orbit have traditionally had to wait as long as ten years for an instrument to be incorporated into a larger satellite and then launched. As Dill says, "That's a significant fraction of your career waiting around to get your data. With a small satellite, you can get a two- or three-year turnaround. You can also get a satellite that's dedicated to your payload. It's a better deal."

LightSats may soon find other market niches. A typical communications satellite might be equipped with 24 separate channels, but it can take up to six years from the time of launch for its parent company to find enough subscribers to use them all. A small satellite with a handful of transponders would be full to capacity from the day it is launched. When the need arises for more channels, a new satellite could be "parked" nearby to take up the load.

And when an existing communications satellite begins to die, it could be cheaper to bring in a LightSat. As Stuart says, "Why not replace the burned-out transponders with a small satellite co-located with the already approved system?" Ball already has a potential customer in mind, assuming the concept is approved by the Federal Communications Commission.

To be sure, the market for LightSats has yet to develop. Dill says, "Right now there are a lot more people trying to sell small satellites than there are people buying them." But the fact that large, established launch companies and satellite manufacturers have begun to pay attention to LightSats should say something. These pioneers think there's a market there—a small one, admittedly—but one they think will grow. Industry analysts, taking into account both the developing market Stuart is after and the more lucrative Defense Department market, think the small satellite business will be worth about $1 billion over the next 10 years.

Not everyone is quite so optimistic. Lawrence Stern, a former NASA strategic planner and now an economics professor at George Mason University in Fairfax, Virginia, is skeptical about the prospects for a LightSat revolution. In a recent study of the small satellite market he declares that the current state of LightSat production consists of "much talk and a comparatively little manufacturing. The small satellite as a commercial product is still in the concept stage."

In part, this is because of some rather imposing economic hurdles. While big companies like Ball are vigorously marketing their LightSats, it's a tougher field for the smaller firms. Financial backing is often difficult to obtain, partly because investors tend to be conservative when it comes to space ventures.

Ironically, notes Stern, the biggest impetus to small satellites has come from the military, long the proponent of bigger and more complex satellites. In particular, the Defense Advanced Research Projects Agency, a small, innovative branch of the Pentagon, has given LightSats a great boost. DARPA's most ambitious project, the Advanced Space Technology Program, has funded most of the new, innovative LightSat technology to date, and has helped to subsidize the development of rockets like Pegasus and Taurus, currently the industry frontrunners.

The Defense Department originally got into the LightSat business as a way of hedging its bets. If World War III were to break out, and Kennedy Space Center and existing U.S. spy satellites were all destroyed, how would the nation reconstitute its space assets? With multiple small satellite launches from elsewhere, DARPA officials reasoned.

Army Major R.J. Bonometti, who works with DARPA's advanced program, says of large spacecraft like Milstar, "No system is fully indestructible." Lightsats will help make sure the U.S. isn't building a Maginot Line in space. DARPA's goal is to develop capable, cost-effective technologies, in part by using the small satellites as testbeds.

Within the military, space has long been the domain of the Air Force, but now other branches of the service are anxious to have access to space. The potential is great. One proposed LightSat, called Microsat, weighs only 50 pounds. A network of seven could relay voice, data and facsimile transmissions, or even slow-speed transmissions of video frames or computer displays, directly to battlefield commanders. One satellite beam could cover all of North Africa and the Middle East.

Another kind of satellite, which DARPA calls MAXSAT (Multiple Access Communications Satellite) can serve the same battlefield commander as a kind of electronic mailbox, relaying data and messages around the world. Also, by receiving data from tactical sensors on the ground, such satellites could provide a backup if more advanced spy satellites were destroyed in a hostile attack. Once such eyes are in orbit, field marshals will be able to see not just over the horizon, but in every direction as far as the conflict extends.

Not everyone within the Defense Department is receptive to LightSats. Former Air Force Secretary Edward "Pete" Aldrich once called them "cheapsats" and tried to drum them out of the DOD budget. Proponents of small military satellites will have to overcome the bigger-is-better, gold-plated procurement process that has become entrenched at the Pentagon.

The coming year will be an important one for the LightSat revolution. A number of small satellites are slated for launch, and the Pegasus booster, for which many LightSats are being designed, will make its first flight.

Dill explains, "I think a lot of [potential customers] are waiting to see how all this works." This is something the LightSat revolutionaries are only too aware of. Fleeter told a gathering last summer, "Do it right the first time. We're not going to get more than one chance in this market to prove what we can do. A lot of small satellite capabilities have been oversold. We have to deliver what we promise." □

Have Guns – Will Travel?

Miramar Naval Air Station in California seems an unlikely spot for a breakthrough in space propulsion. But shrouded in secrecy on a remote corner of the base is a 30-foot-long weapon–an anti-tank gun–that could change the way small satellites are launched into Earth orbit.

Developed at Maxwell Labs by the Defense Department as a way to pierce enhanced Soviet armor, the Miramar electromagnetic gun uses electric current instead of gunpowder for its propulsive force. Projectiles in the gun's breech reach unprecedented velocities–in the range of two to five miles per second.

But blasting big holes in armor plate isn't what has some people in the world of electromagnetic propulsion so excited. For the first time, the Miramar Gun and similar mechanisms at the University of Texas, Eglin Air Force Base in Florida, Sandia National Labs and other locations can provide enough raw muscle to blast small packages into space, at a low enough cost that independent corporations and research institutions may find them affordable.

"[Electromagnetic Space Launch] opens a door for opportunities we never thought of before," says Harry Fair of the University of Texas Center for Electromechanics. "EMSL could certainly put every country or maybe even a number of industries in the satellite launch business."

Even the most efficient rocket programs burn a major portion of their investment with every launch. At $200 million per flight, NASA's space shuttle may as well be spewing hundred dollar bills from its rocket nozzles.

That's where EMSL fits in. Miles Palmer, a former Air Force Weapons Lab physicist now at Science Applications International Corporation (SAIC), puts it this way: "An Electromagnetic Space Launcher is a capital asset like a factory, which continues to produce as long as you provide raw materials to the breech. Unlike rockets, EMSL doesn't blow up and it doesn't fly away."

Palmer's proposed "launch factory" could hurl a 40- to 400- pound satellite into orbit every five minutes, at around $10,000 per launch–roughly one hundredth to one thousandth the cost of a small conventional rocket like the Scout. Several electromagnetic guns are already in operation. Most can, on demand, fire projectiles with enough velocity to escape Earth's atmosphere.

Lucrative as it seems, however, we're not likely to see privatized EMSLs until the government further develops the technology and builds a functional prototype. NASA, meanwhile, remains officially uninterested in electromagnetic space launch. The agency's most recent study of EMSL in 1984 took the position that the technology should work and work cheaply, but that there was no demand for it.

"They [NASA] are looking for the best way to kill this thing in its infancy before it becomes a threat to their rocket programs," claims one suspicious EMSL researcher. Others say it's not so much a question of malice as unimaginative thinking. According to one corporate physicist, "Talking to NASA about Earth to space electromagnetic launch is like talking to a buggy whip manufacturer about automobiles." Carolyn Meinel, a former defense research contractor, laments, "They [NASA] are not interested unless it's solidly based on a 1950s concept."

But some NASA researchers, like Ross Jones of the Jet Propulsion Laboratory, are actively campaigning for a prototype EMSL. Jones has proposed "micro-spaceprobes," using space-based electromagnetic launchers to

send coffee can-sized packages on interplanetary missions. Bill Scallion of NASA's Langley Research Center has suggested using an electromagnetic gun for hypervelocity aerodynamic research. His device would provide hypersonic modeling for advanced craft like the National Aerospace Plane. Although Scallion is aware of the space launch potential of electromagnetic guns, he is more comfortable with conventional applications for now.

That leaves the Defense Department as a possible source of funding for a prototype EMSL. Up until now the Army, the Defense Nuclear Agency, the Defense Advanced Research Projects Agency (DARPA) and other branches of the military have nursed electromagnetic technology from graduate student experimentation into today's revolutionary hardware. Why would the Pentagon be interested in space applications? Peter Kemmey, a DARPA physicist and leading electromagnetic pioneer, says that "For military purposes, Earth to space electromagnetic gun launches are less observable."

Miles Palmer of SAIC believes the best way to demonstrate EMSL capability would be a quick and dirty sounding launch, using existing devices like the Miramar or Eglin guns. Since they've already achieved velocities greater than 2.1 miles per second, Palmer would simply elevate the barrel and let it rip. That should be sufficient to loft a two-pound package to an altitude of around 250 miles–a typical sounding rocket mission–before falling back to Earth. The demonstration would require no development–the hardware exists today. In fact, such a test is planned at Eglin early in 1990.

As a next step, Palmer proposes building a $50 million prototype launcher. This device would be about 100 yards long, and could be powered by car batteries–the same cheap and easy power source used for the gun at Eglin AFB. Once the bugs are worked out of the prototype, Palmer believes follow-on full scale EMSLs could, if built in quantity, cost as little as $10 million each, which would put a "launch factory" within reach of many corporations.

At least one giant aerospace company has shown interest in the technology. General Dynamics Space Systems Division is, in the words of marketing manager Lee Patterson, "Cautiously assessing EMSL at the division level. The technology is such that it can be done....We're cautiously optimistic."

Eddie Leung, General Dynamics' chief electromagnetic engineer, says, "We feel that there will be a cost savings in terms of both capital and operating costs. It's probably going to be at least one, and possibly two, orders of magnitude reduction compared to rockets." Leung emphasizes, however, that EMSL "will not replace rockets. It's meant to compliment them rather than replace them. EMSL works best with small packages, where it has the advantage of quick response time and flexibility."

General Dynamics' design, if built, would move EMSL into the big leagues. With a length of two to four miles and a bore size of 30 inches, this superconducting coil launcher could blast a 2200-pound mass into low Earth orbit. Smaller packages could conceivably reach escape velocity, giving the launcher an interplanetary reach.

The long launch tube is designed to counter one of EMSL's most notorious problems–extremely high acceleration forces. Devices like the Miramar Gun, with its short 30-foot tube, subject payloads to more than 50,000 g's as they blast out of the barrel. Accelerating from zero to two miles per second in 30 feet will squash most conventional electronics like a bug on a windshield.

But EMSL proponents say they have an answer. The Pentagon's SDI organization believes electronics can be modified to withstand the rigors of a short barrel gun launch by "hardening" the sensors. Toward that end, SDI has funded Project LEAP (Lightweight Exoatmospheric Projectile) to develop four-pound projectiles that would include not only guidance capability but also manuevering thrusters–all able to withstand 50,000 g's. While SDI is interested in building missile interceptors, the same hardened electronics could be applied to microspacecraft.

With a two-mile launch tube, such precautions might not be necessary–accelerations would be slower and more gentle. Estimates of the capital investment required to build such a device run around $600 million. Once that expense is amortized, the launch energy costs would be under a dollar per pound of payload.

Most EMSL experts say we're still a long way from backyard space launchers. But they also argue that EMSL is such a simple, inexpensive technology that it offers the first practical opportunity to de-monopolize space commerce.

–Terry L. Metzgar

Star City

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engineers who created it, and the best way to realize a "spinoff" from the project could be to cancel it altogether and reassign personnel throughout other ailing Soviet industries. Buran's termination would simultaneously mollify a hostile public and an embittered scientific establishment.

Speaking to the Congress of Deputies last May, Mikhail Gorbachev stressed his acceptance of the profit motive for space spending: "The latest developments made during the Buran project alone could have significant benefit–worth billions of rubles–if they are passed on to national economic enterprises and organizations," he said. "One must bear in mind that only if that happens will the money we spend to master space be justified."

But with an aroused public demanding action, space is a handy scapegoat, already tried and convicted in the court of public opinion. If space spending takes the blame for the deeper maladies that afflict Soviet industry, cutting it may be the wrong cure. Buran and other projects would be strangled for short-term political benefits, which would be followed only by deeper economic collapse. It is not an auspicious forecast.

Meanwhile, Soviet space officials will have to learn how to answer the question that has long plagued their American counterparts: Is the space program worth it? □

James Oberg is a long-time observer of the Soviet space program. His books include Red Star in Orbit, The New Race for Space *and* Uncovering Soviet Disasters.

Flag burners in space

Gerald Carr

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grind, because Skylab had no real color. It was mostly very dull, either white or very light pale green or tan, or metallic. The quarters had no real pleasantness and not much capability to personalize them other than maybe to tape your family pictures to the door of a locker. I think six months in Skylab would have been pretty tough. After 84 days we were feeling like it was a pretty monotonous place to live.

I don't think you have to gold plate it. A little color doesn't cost a lot of money. Some texture on a wall doesn't cost a whole lot of money. But if you start talking video games and a personal VCR in every crew quarters and that kind of stuff, you're probably talking about a little bit more money than folks want to spend.

I think the longer you keep people up, the more amenities you had better be prepared to provide. You can frustrate human needs for short periods of time, but as the time gets longer you had better start satisfying them.

Shuttle crews, for example, might be perfectly satisfied with a tray that straps to your lap so you can squat down in a corner somewhere and eat your meal. But after you've been up there a longer time, that isn't quite as pleasant a way to have your meal. It really is nice to have a gathering place where you can recapture a little bit of Earth life and have a meal together and conversation over the table.

On shuttle flights you could schedule people right up to the hilt. You could work them until they were crazy and tired, but they knew that after seven or ten days it would be all over and they could catch up on their sleep and get their sense of humor back. So everybody was willing to do that because they could. Their stamina would allow them to do it.

But when you start stretching missions out to 30, 60, 90 and 180 days, you have a whole different kind of mindset that you have to deal with. In fact, people are going to go up there and set up housekeeping. They're not on a camping trip.

The indications we're getting from the Soviets are that toward the end of their long missions they were getting not much more than about two and a half hours of productive work out of a given day. It's kind of sobering that we might end up that way on space station. But quite frankly, I don't think we will, because the Mir is a rather austere environment. And if you take care of the amenities and keep people motivated, my guess is that folks on space station

will be significantly more productive than what Soviet experiences have been so far.

Final Frontier: What about the people who will command the space station? Will they have to be different personalities from shuttle commanders?

Carr: I don't know about that. Leadership is leadership. The big thing you have do for the [space station commander] is to teach him the skills to manage the situation. In the past our leaders have not had to deal with interpersonal kinds of problems and stress management and stuff like that, whereas I think in this case they are going to need it. I can't help but think that the guys who led well before wouldn't lead just as well in this situation if given the right kind of training and experience.

Final Frontier: On the space station you're going to have crew members from different cultures. Will that cause any problems?

Carr: I don't think so. I think it is going to be important that people be trained and understand and know each other beforehand. For instance, if you have a whole crew full of Christians and you have two Moslems on with you, the Christians need to understand where the Moslems' religious beliefs' lap into their daily life. By the same token, the Moslems need to understand the Christians. There is going to be, I think, a necessity for people to get trained on how people of different cultures deal with things like anger and frustrations.

Final Frontier: Is there any need for a space station simulator where people could actually live and work together on the ground before they go up in orbit?

Carr: There is a lot to be said about that. We did mini-sims before Skylab in which we were able to look at whole days of activities and try to put all of these parts together and see how a day worked. I think it is going to be important that we do that on space station as well. There are ways that can be done. A crew could go to the Antarctic and spend 90 days together in an outpost working together and doing a lot of the work they would be doing together and understanding the group dynamic. You could just put them in a simulator in Houston or somewhere in the U.S. and keep them together for a period of time in order to give them an opportunity to feel out the group dynamic.

Final Frontier: Is that in the planning now?

Carr: No. I think people are still wrestling about just how to go about it, but I think we will end up having to do something like that. □

Ed Gibson

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ought to have the ground and the person onboard working in harmony, with each consulting the other, and not have tele-science be strictly "tele-robotic." In other words, you can't just use the guy up there as a high-priced robot for the guys on the ground. That doesn't make sense. Then you've got the wrong guy up there.

If, however, you have 20 different experiments and no one onboard can be expert in all of them, then the onboard guy makes the first cut at running it, and the guys down on the ground can critique it and give some real time updates.

Final Frontier: Some people raise the question of whether you can do all types of science on one platform.

Gibson: Well you really can't, not in the optimum. It's going to be a compromise initially. You're looking for two different kinds of space stations, depending on whether you come at it from a materials science standpoint, where you want a perfectly still station with no vibration and a lot of power, versus life science, where you need less power, and you can tolerate a lot of vibration.

But I can see the day, once we get a little further along, when we're going to find ways to break off materials processing into something like the proposed Industrial Space Facility. Once we get a little smarter on how to let experiments run for a longer period of time [automatically] you could put them out in the industrial facility. So I think, in the very long-term, we're talking about multiple stations up there.

But right now we really don't know what we are trying to go after. Materials processing in space is in its infancy. It's like a lab down here–you've got to get some day-to-day, hands-on experience at trying various things before you fully develop them. That's what a space station is all about.

Final Frontier: Do you think there's some under-appreciated area of research that will become important on Freedom?

Gibson: Yes, one thing we've always tried to sell, without a great deal of success, is manned Earth observation. Landsats and other Earth-viewing satellites are extremely valuable, but there is a whole host of Earth sciences which can benefit by having a human observer up there.

If you think about yourself being

above the Earth, you've got choices in the direction you look, in the wavelength you observe in, and the time when you observe. Fault zones, for example, are more or less apparent depending upon the angle of sunlight. You can see weather patterns like thunderstorms and try to understand the interrelationships, or watch lightning ripple through a whole cloud system that covers half the country.

There's a whole host of things that go on in our atmosphere and oceans which are very transient, and which depend on how and when you look at them. I think there is just so much more that can be done, and human observers may help you design sensors to get better data.

Final Frontier: When you make these kinds of arguments, do the people working on Freedom listen to you and the other Skylab astronauts?

Gibson: Well, to some degree. We occasionally get asked, but most of it is going to evolve on its own. I think they're going to have to learn their lessons all over again, to be truthful. □

Bill Pogue

continued from page 45

country—if we don't understand it too well, we overkill it by a factor of ten.

I wish I were smart enough to know exactly what tests to do to minimize the impact on the crew. But personally, I did not like being the guinea pig [on Skylab], and I don't think any of the current astronauts like to be guinea pigs.

Final Frontier: You're talking about the reluctance by the biomedical people to commit to stays longer than 90 days?

Pogue: Yes. I'm sensitive to the medical profession's need to understand what's happening to the human body. Intellectually, I appreciate the need for doing some medical testing to make sure we're not going to hurt somebody or cause some kind of long-term medical problem. On the other hand, as a crew member who's participated in a lot of those medical tests, I just got sick and tired of them. I don't like having to weigh in every time I go to the toilet, or have blood drawn every two weeks. I think that probably what's going to happen is that they'll make the tests less invasive, to which I say "Hooray!" The medical testing can get to the point where it's highly detrimental to the operations onboard. That's the

dilemma you're dealing with.

Final Frontier: Why not have a designated medical guinea pig on the crew?

Pogue: Well, that's exactly what we said: "Send your own subjects up." And they'd probably have more than enough volunteers. But you can't just go up there and do nothing but medical tests on people. Although it would be nice to have dedicated test subjects, the truth of the matter is you can't afford it. You have to justify anywhere from $25,000 to $36,000 an hour, which is what it costs for a crew member to be up there.

Final Frontier: Can you think of some piece of equipment or procedure that would have made your life on Skylab easier, something that they should have onboard Freedom?

Pogue: One of the things they have on the shuttle now, but which we did not have, was a way of accessing flight dynamics data to determine where you are at any specific time. We could do this manually, with a map on Skylab, but it was not easy to figure out when, say, you were going to go over Chicago.

The thing I think will really be a big help is a level of automation on the space station that relieves you from trivial and boring tasks. For instance, I had one instrument on Skylab that I had to turn on, and it took only one second to flip the switch. But I had to do it at a certain time. And it was one of the more irritating tasks I had to do, because I had to mentally program myself, while I was doing other work, to remember it. Twice I didn't do it, because I had a mental lapse. That could have very easily been automated.

The systems don't have to be ultra-sophisticated to relieve the crew members of a lot of nagging or irksome work.

Final Frontier: Anything else you wished you'd had when you were up there?

Pogue: Yes. Instrument simulators. Flying an instrument without a good Earthbound simulator is complete folly. We had a couple of instruments for which we had never seen a display or the actual view until we got up there. I fouled up one investigation in particular, because I was looking in this thing and seeing what I thought was the horizon of the Earth, and after two or three sessions, I finally realized I was seeing the reflection of my cornea in the lens. We didn't have a simulator for that, and I didn't quite know what to look for. I don't think that's going to be a problem, though. I think we've learned our lesson on that one. □

Liftoff! The Race to the Moon Game
By Fritz Bronner
Task Force Games
$28.95

Space Shuttle Adventure
Solar Wind Toys
$25.00

By Tony Reichhardt

Why are some board games fun for the whole family, and others the death of the party? What makes shoppers claw at each other to grab the last box of Trivial Pursuit off the shelf, while I have yet to meet a single person who's ever played Perquacky? If we knew, we'd all have a million dollars, and not just in Monopoly money. Apparently there's more to creating a hit game than a couple of dice and Art Linkletter's stamp of approval.

Although neither "Liftoff!" nor "Space Shuttle Adventure" are likely to wind up in every toy closet in America, they rely on proven formulas, and for the most part they succeed in translating the space program to the game board.

"Space Shuttle Adventure," which is marketed through catalogs, specialty stores, museums and a limited number of retail stores, makes for a pleasant half hour of diversion. The play is straightforward, maybe even a bit too simple. The first person to round the board and land their shuttle wins.

The game has enough trinkets (the markers are little shuttles) to keep kids entertained, and if you actually want to learn something about EVA's and APU's as you hop from square to square, there's a glossary that gives a good—but not too detailed—explanation of the terms you encounter during your shuttle "mission."

The obstacles—malfunctioning fuel cells, broken down tracking satellites and the like—are realistic enough to

remind you how annoying real shuttle delays are, but somehow it all keeps moving. I was happily discovering new galaxies and performing spacewalks until my pilot was blinded by a Sun burst. Who knows, if my ten-year old niece hadn't gotten four lucky rolls in a row, I might even have won without cheating.

If it's complication you want, try "Liftoff!" Remember those war strategy games in eighth grade, where players re-created the Battle of Anzio in their parents' den for weeks on end? (I always gave those guys a wide berth when I passed them in the hallway, and made a point to smile.) "Liftoff!" offers a similar level of detail as it faithfully represents the events that led up to the Apollo 11 Moon landing in 1969.

It won't take weeks–the game's creators say it should take from three to five hours to play– but "Liftoff!" *does* require an investment of time and concentration. Never having tried one of these strategy games, I found myself frustrated just getting through the 20-page instruction manual, which reads in places like a tax form. My recommendation, unless your friends are exceptionally patient, is to study the instructions thoroughly before you invite them over, so you don't have to consult the manual at every step.

But once play begins, "Liftoff!" makes for an absorbing time. Four teams–from the United States, Soviet Union, Europe and Asia–conduct a sequence of space missions leading up to the manned lunar landing that wins the game. Play begins in 1956, and essentially retraces the history of the U.S. space program, beginning with orbital satellite missions and progressing up through manned flights of one, two and three astronauts.

Each player receives "megabucks" every year with which to buy hardware and invest in research, and the budget rises or falls depending on "event cards" that represent, among other things, the vagaries of political support and how well your test programs go.

In most cases, the prudent thing to do is to go slowly and invest in the research that improves your chance of succeeding. But you can rush your missions if you want; it simply costs more money and reduces your safety margins. (By sheer luck, two of my brave astronauts, Lt. Yee and Lt. Kim, completed the equivalent of a Gemini mission onboard their Futari two-person capsule in 1958, instead of in 1965, as NASA did.)

If you want to make things even more involved, there are plenty of advanced rules about espionage, diplomacy, rescues, even bartering among the different nations. It all rings true, in more ways than one. Despite all the strategizing, a lot of times it seems to come down to a roll of the dice. Which, come to think of it, is probably the way NASA managers feel sometimes. □

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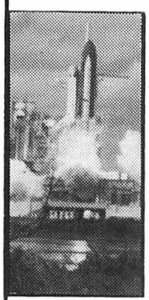

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